



Review

Sustainable Applications of Endophytic Bacteria and Their Physiological/Biochemical Roles on Medicinal and Herbal Plants: Review

Phumudzo Patrick Tshikhudo ^{1,*} , Khayaletu Ntushelo ² and Fhatuwani Nixwell Mudau ³

¹ Department of Agriculture, Land Reform and Rural Development, Directorate Plant Health, Division Pest Risk Analysis, Arcadia, Pretoria 0001, South Africa

² Department of Agriculture and Animal Health, College of Agriculture and Environmental Sciences, University of South Africa, Private Bag X6, Florida 1710, South Africa

³ School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Private Bag X01, Scottsville, Pietermaritzburg 3209, South Africa

* Correspondence: tshikhudopp@gmail.com

Abstract: Bacterial endophytes reside within the tissues of living plant species without causing any harm or disease to their hosts. These endophytes can be isolated, identified, characterized, and used as biofertilizers. Moreover, bacterial endophytes increase the plants' resistance against diseases, pests, and parasites, and are a promising source of pharmaceutically important bioactives. For instance, the production of antibiotics, auxins, biosurfactants, cytokinin's, ethylene, enzymes, gibberellins, nitric oxide organic acids, osmolytes, and siderophores is accredited to the existence of various bacterial strains. Thus, this manuscript intends to review the sustainable applications of endophytic bacteria to promote the growth, development, and chemical integrity of medicinal and herbal plants, as well as their role in plant physiology. The study of the importance of bacterial endophytes in the suppression of diseases in medicinal and herbal plants is crucial and a promising area of future investigation.

Keywords: antimicrobials; secondary metabolites; plant growth promotion; phosphate solubilization; nitrogen fixation; phytoremediation



Citation: Tshikhudo, P.P.; Ntushelo, K.; Mudau, F.N. Sustainable Applications of Endophytic Bacteria and Their Physiological/Biochemical Roles on Medicinal and Herbal Plants: Review. *Microorganisms* **2023**, *11*, 453. <https://doi.org/10.3390/microorganisms11020453>

Academic Editors: Carlos Barreiro and Carlos García-Estrada

Received: 15 January 2023

Revised: 2 February 2023

Accepted: 6 February 2023

Published: 10 February 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

It is well known that users of endophytic bacteria employ comparable strategies to enhance plants growth. In addition, endophytic bacteria are more successful than rhizobacteria at reducing the negative impacts of environmental stressors on plants. They enter the plant tissue primarily through the roots and other natural openings in the plant. After entering the plant, bacterial endophytes may spread throughout the tissues of the host plant [1]. Medicinal and herbal plants have secondary metabolites which function as important drugs, flavor, fragrances, agrochemicals, dye, pigments, pesticides, and may play a key role in the adaptation of plants to their environment [2].

Bacterial endophytes of the genera *Bacillus*, *Pantoea*, *Pseudomonas*, *Stenotrophomonas*, and *Serratia* can produce phytohormones, such as auxin and gibberellin, as well as protease and hydrogen cyanide, and play a role in siderophore production, phosphate solubilization, and atmospheric nitrogen fixation [3]. Among other endophytes, *Bacillus*, *Pseudomonas*, *Agrobacterium*, and *Flavobacterium* species solubilize the inorganic phosphate compounds by phosphatases. Bacterial species of the genera *Alcaligenes*, *Arthrobacter*, *Azotobacter*, *Bradyrhizobium*, *Chromobacterium*, *Enterobacter*, *Escherichia*, *Micrococcus*, *Streptomyces*, *Serratia*, and *Thiobacillus* secrete organic acids to solubilize the insoluble phosphorus. *Pseudomonas* spp. and *Bacillus* spp. are known endophytes that are involved in siderophores production [4]. For example, secondary metabolites produced by endophytic bacterium *Bacillus pumilus* have a significant inhibitory effect against fungal species, such as *Pythium aphanidermatum*, *Rhizoctonia solani*, and *Sclerotium rolfsii* [5]. The leaf and stem of heart-leaved moonseed

(*Tinospora cordifolia* (Thunb.) Miers) contain *Bacillus*, *Aneurinibacillus*, and *Pseudomonas* species [6]. Traditional medicine has long utilized *T. cordifolia* to treat several conditions including fever, jaundice, chronic diarrhea, cancer, dysentery, bone fractures, pain, asthma, skin diseases, deadly bug bites, and eye issues.

Nitrogen-fixing bacterial strains are linked with certain leguminous and non-leguminous species [7]. Species such as *Gluconacetobacter diazotrophicus* and *Azorhizobium caulinodans* can fix nitrogen [8]. *Pseudomonas putida*, *Azospirillum brasilense*, and *Enterobacter cloacae* enable plants to grow and survive under higher levels of polyaromatic hydrocarbons (PAHs) through phytoremediation [9]. *Arthrobacter* sp. and *Bacillus* sp. bacterial endophytes produce secondary metabolites for plants to adapt to abiotic stress [10]. Several studies have shown that endophytic bacteria play a beneficial role in plant growth. It is not yet clear which bacterial strains contribute more to the growth and development of medicinal plants. It is well-known that the density of endophytic bacteria within the plant tissues is less than that of found in the rooting zone [11]. Plant-growth-promoting (PGP) bacteria that fix nitrogen may be used as biofertilizers to improve plant growth [12]. Many of these bacteria also produce phytohormones [13]—for example, as the bacterial strain SCCPVE07—that improve the growth of coriander (*Coriandrum sativum* L.) grown under salinity stress [14]. The stem and leaves of coriander have antimicrobial and antibacterial qualities. Inoculated *C. sativum* showed higher levels of calcium, carbon, iron, and potassium contents. In this case, the levels of cinnamic acid, 4-methoxy-cinnamic acid hexoside, 5-O-caffeoylquinic acid, K-3-O-rutinoside, Q-3-O-rutinoside, Q-3-O-glucoside, and Q-3-O-glucuronide were significantly increased [15]. In addition, certain plant species are capable of accumulating heavy metals and soil contaminants in their tissues [16].

In this context, we aim to provide a review of the sustainable applications of endophytic bacteria and their physiological and biochemical processes on medicinal and herbal plants to lay a foundation for future studies intended for the isolation, identification, and characterization of endophytic bacteria from the internal tissues of medicinal and herbal plants. Understanding these functions might lead to the development of new techniques in agricultural and biotechnological environments, specifically for the future cultivation and commercialization of indigenous medicinal and herbal plants.

2. Potentialities of Endophytic Bacteria

In this regard, this research thoroughly examines several bacterial endophytes and their potentialities on herbal plant species without inflicting any harm or disease to their hosts, drawing on a variety of sources in the literature. These endophytes can be isolated, recognized, and characterized in addition to being employed as biofertilizers to improve plant development and change the chemical makeup of the plant. Additionally, bacterial endophytes boost plants' resilience to diseases, pests, and parasites and are a promising source of bioactives with the potential for use in pharmaceuticals (Figure 1). For instance, the existence of distinct bacterial strains is credited with the synthesis of antibiotics, auxins, biosurfactants, cytokinins, ethylene, enzymes, gibberellins, nitric oxide organic acids, osmolytes, and siderophores. In order to enhance the growth, development, and chemical integrity of medicinal and herbal plants, as well as their function in plant physiology, this manuscript reviews sustainable applications of endophytic bacteria. It is critical to examine the role of bacterial endophytes in the control of illnesses in medicinal and herbal plants—a promising avenue of future research.

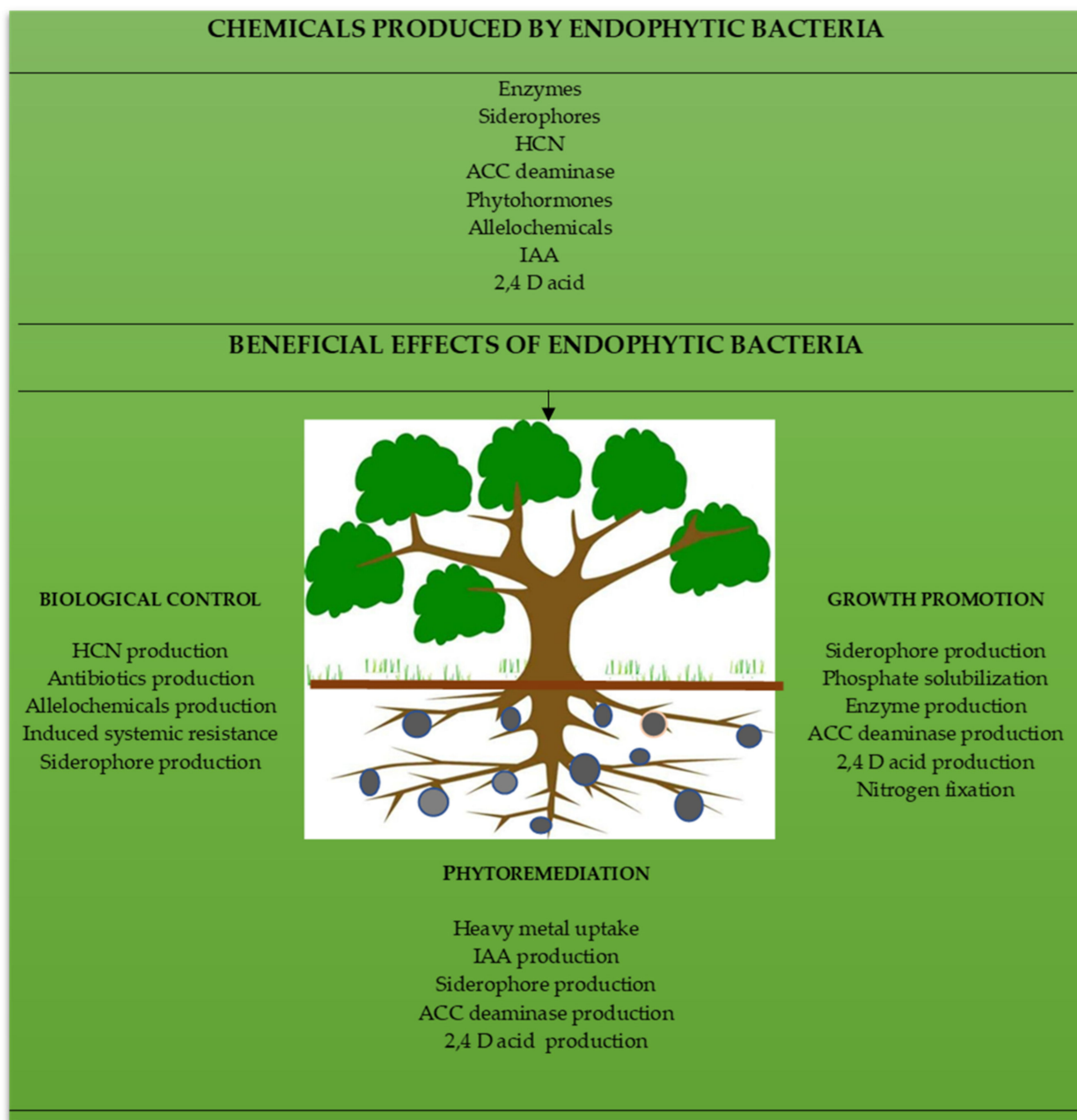


Figure 1. Roles of endophytic bacteria on plant growth, protection, and phytoremediation.

2.1. Growth-Promoting through Nitrogen Fixation, Phosphate Solubilization and Anti-Pathogenic Capabilities

Endophytic bacteria have been increasingly associated with the ability to suppress a broad pool of plants diseases, with this ability being closely associated with the vegetative growth and chemical composition of the plant [17]. Different alkaloids contribute to plant defense through endophytes action, acting as growth-promoting compounds or having a key role in plants' resistance to environmental stress. Amines and amides, very common metabolites from endophytes, present toxic activities against insects. Steroids, terpenoids, and diterpenes are also generated by endophytes [18] and are responsible of several activities such as plant-growth promotion and yield, suppression of pathogen-growth and colonization, contaminants remotion, phosphate solubilization, and nitrogen plant-assimilation [19]. These properties may be helpful in organic tea plantation [20,21].

Pseudomonas and *Bacillus* spp. were studied for their role against blister blight disease caused by *Exobasidium vexans* in tea plants [22]. *Pseudomonas fluorescens*, applied at 7-day intervals, reduced the disease incidence for two seasons to the same level as a fungicide and increased tea yield. Chemical analysis of the plant showed that there was induction of phenolics compounds and defense enzymes, such as peroxidase, polyphenol oxidase, phenylalanine ammonia lyase, chitinase, and β -1,3-glucanase. *Methylobacterium radiotolerans* MAMP 4754 was isolated and identified from the seeds of the therapeutic plant *Combretum erythrophyllum* in order to explore the endophyte's antibacterial and antioxidant properties [23]. Basil (*Ocimum sanctum* L.) plants have antimicrobial, immunomodulatory, antistress, anti-inflammatory, antipyretic, anti-asthmatic, hypoglycaemic, hypotensive, and analgesic properties [24,25].

Endophytes living within a healthy plant are a good source of antimicrobial agents, enzymes, and secondary metabolites [24]. For example, endophytic bacterial strains isolated from *O. sanctum* leaf tissues are antagonistic to pathogenic fungi, such as *Alternaria solani*, *Fusarium solani*, *R. solani*, *S. rolfsii*, and *Colletotrichum lindemuthianum* [26], and are therefore capable of promoting the *O. sanctum* growth. Interestingly, *O. sanctum* treatment with these bacterial endophytes increased the content of plant essential oil, with this demonstrated influence of bacterial endophytes on *O. sanctum* growth and oil content [26]. Bacterial endophytes inhibited six out of ten test microorganisms [24]. Among these, *Salmonella typhi*, which is a typhoid-causing bacterium, was significantly inhibited by 3 bacterial isolates (BTS 2, GTL 3, BTS 4), while 2 bacterial isolates (BTS 2, GTL 3) significantly inhibited *Micrococcus luteus*, an opportunistic pathogen. Medicinal species, such as seepweed (*Suaeda nudiflora* Thwaites), white-flowered black mangrove (*Lumnitzera racemosa* Willd.), beach moonflower (*Ipomoea tuba* (Schltdl.) Colla), and mangrove (*Avicennia alba* Blume) have different levels of antimicrobial activities against *M. luteus*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Klebsella pneumonia*, and *Bacillus subtilis* [27].

In China, *Glycyrrhiza* spp. are regarded as the most important herbs to treat blood disorders, cancer, and hepatitis, and these plant species are thought to improve the immune system while reducing chemotherapy-related side effects [28]. *Glycyrrhiza* spp. have antimicrobial activity [29]. Licorice (*Glycyrrhiza glabra* L.) is a perennial shrub that contains glabridin which is specifically derived from the plant's roots [30]. *G. glabra* is used to manage ulcer and respiratory problems [31]. Licorice (*Glycyrrhiza uralensis* Fisch. ex DC) is a leguminous herb that is native to Asia [32], but it is now grown in many parts of the world [32]. The roots of *G. uralensis* produce a variety of terpenoids and flavonoids. Bacterial strains were isolated from the root nodules of *G. uralensis* and *G. glabra* to identify and classify them, as well as to determine their level of stress tolerance [30,32]. Based on 113 physiological and biochemical characteristics, the isolates were clustered into three groups. One bacterial isolate, which belongs to the genus *Mesorhizobium*, has a high tolerance to NaCl, pH, and high temperatures.

Nodulation tests demonstrated that this isolate also formed nitrogen-fixing nodules on other plants, namely sophora (*Sophora viciifolia* Hance), bird's-foot trefoil (*Lotus corniculatus* L.), white clove (*Trifolium repens* L.), melilot (*Melilotus suaveolens* Ledeb.), and bitter licorice (*Sophora alopecuroides* L.). *S. alopecuroides* has been used as a traditional Chinese medicine to treat fever and diarrhea, among other diseases, as well as to inhibit cancer cell growth [33,34]. 16S rRNA and recA gene analyses revealed the presence of *Agrobacterium tumefaciens*, *Mesorhizobium alhagi*, *Mesorhizobium gobiense*, *Mesorhizobium amorphae*, *Phyllobacterium trifolii*, *Rhizobium giardinii*, *Rhizobium indigoferae*, *Sinorhizobium fredii*, and *Sinorhizobium meliloti* from the root nodules of *S. alopecuroides* in different regions of China's Loess Plateau [35].

Ginger (*Zingiber officinale* Roscoe) is an important medicinal plant, producing aromatic rhizomes which are valuable both as spice and herbal medicine [36]. Ginger has been used as a traditional medicine in China and India for more than 25 centuries [37]. However, ginger wilt provoked by *Ralstonia solanacearum* is a severe disease which threatens the productivity of ginger in China. Ginger has anti-inflammatory, anti-emetic, and chemo-

protective properties [38]. Bacterial strains were isolated from the plant surface as well as the stem, leaf, and root tissues of *Z. officinale* for their antimicrobial activity against *R. solanacearum* using amplified ribosomal DNA restriction analysis (ARDRA) fingerprint analysis [36]. It was also found that the isolated bacterial strains had the ability to produce certain enzymes and metabolites which exert a significant reduction in disease occurrence when the antagonists were applied.

Rooibos tea (*Aspalathus linearis* (Burm.f.) R.Dahlgren) is the source of commercialized rooibos tea, which is endemic in the mountains of the Western Cape province in South Africa [39]. *Burkholderia tuberum* was originally isolated from *Aspalathus* sp. (rooibos tea plant) nodules in South Africa [40]. Sequence analysis of the 16S rRNA showed that endophytic bacterial isolates were beta-rhizobia [39]. Rooibos tea contains no colorants, additives, or preservatives and is free of caffeine. Bush tea (*Athrixia phylicoides* DC.) is indigenous to Southern Africa. *A. phylicoides* is used for cleansing or purifying blood, treating boils, headaches, infected wounds, and cuts [41,42]. Vhavenda people believe bush tea has aphrodisiac properties [43]. Traditionally, Zulu people prefer bush tea decoction extracted from the root as a cough remedy and purgative [44], whereas the Sotho people use bush tea as a soothing wash for sore feet [45,46]. It is known that leaves of bush tea contain 5-hydroxy-6,7,8,3',4',5'-hexamethoxy flavon-3-ol [41,47], 3-O-demethyldigicitrin; 5,6,7,8,3',4'-hexamethoxyflavone and quercetin [48], total polyphenols [41,48,49], tannins [49], and total antioxidants [50–52].

Echinacea spp. contain polysaccharides, glycoproteins, alkamides, volatile oils, and flavonoids [53]. The echinacea herb is used for the treatment of flu and colds [54]. Endophytic bacteria of the genera *Acinetobacter*, *Bacillus*, *Pseudomonas*, *Wautersia* (*Ralstonia*), and *Stenotrophomonas* were identified and characterized from the medicinal plant *Echinacea* spp. by means of 16S rRNA gene analyses and other microbiological tests such as thin-layer chromatography (TLC) and high-performance liquid chromatography (HPLC). It was also discovered that the *Pseudomonas stutzeri* P3 strain produces the plant indole acetic acid [40]. In terms of antibiotic resistance, it was found that most endophytic bacterial isolates were resistant to the antibiotic kanamycin.

Bacillus, *Brachybacterium*, *Kocuria*, *Leucobacter*, *Lysinibacillus*, *Mycobacterium*, *Paenibacillus*, *Pseudomonas*, *Providencia*, *Rhizobium*, and *Streptomyces* have been isolated from *Polygonum cuspidatum* Sieb. et Zucc. and identified using 16S rDNA sequence. *P. cuspidatum* produces polydatin, a glycosylated derivative of resveratrol. These endophytic bacteria isolated from *P. cuspidatum* have inhibitory activity against *Aspergillus niger*, *Aspergillus fumigatus*, *B. subtilis*, *Gibberella fujikuroi*, *K. pneumoniae*, and *S. aureus* [55]. From the roots and leaves of Radish (*Raphanus sativus* L.) at Jinju, Korea, *Proteobacteria*, *Bacillus*, and *Bacteroidetes* spp. were isolated using phylogenetic analysis based on 16S rDNA sequences. *B. subtilis* exhibited amylase, cellulase, xylanase, mannase, PGAase, DNase, protease, and esterase and inhibitory action against plant pathogenic fungi [56]. In China, *R. sativus* is used to treat hypertension, chronic tracheitis, and constipation.

Extract of endophytes isolated from creat or green chiretta (*Andrographis paniculata* (Burm. f.) Wall. ex Nees) contains antibacterial activities against human pathogenic bacteria [57]. From internal tissues of the root and stem of *Piper nigrum* L., endophytic bacterial species such as *Pseudomonas* spp., *Serratia* spp., *Bacillus* spp., *Arthrobacter* spp., *Micrococcus* spp., and *Curtobacterium* sp. (1 strain) were isolated and identified based on 16S rDNA sequencing and found to be effective antagonistic endophytes for the biological control of *Phytophthora capsici* [58]. White Tree Peon (*Paeonia ostia* T. Hong and J.X.Zhang) is an important medicinal plant of China, and 56 endophytic bacterial strains were identified by 16S rDNA gene sequence analysis. These bacterial endophytes contain non-ribosomal peptide synthetase and putative polyketide synthase genes responsible for bioactivities [59].

Pseudomonas aeruginosa isolated from balloon flower (*Platycodon grandiflorum* (Jacq.) A. DC.) degraded 2,4-Dichlorophenoxyacetic acid which is responsible for antimicrobial activity against pathogenic fungus causing balloon flower root rot [60]. Endophytic bacteria isolated from the leaves of pennywort (*Centella asiatica* (L.) Urb.), *B. subtilis* BCA31, and

P. fluorescens BCA08 reduced the growth rate and disease incidence of the causal agent of anthracnose *Colletotrichum higginsianum* [61]. The endophyte *B. subtilis* ALB629 isolated from cacao seedlings has antimicrobial properties against fungi *Moniliophthora perniciosa* and *Colletotrichum gossypii*. *B. subtilis* ALB629 promotes growth of both the aerial and roots of cacao seedlings [62]. 16S rRNA sequence analysis revealed *Bacillus*, *Streptomyces*, *Pseudovibrio*, and *Pseudomonas* species isolated from *Rhizophora stylosa*. These isolates had antimicrobial activity against *E. coli* ATCC 25922, *P. aeruginosa* ATCC 25923, *B. subtilis* ATCC 27212, *S. aureus* ATCC 12,222, and *C. albicans* ATCC 7754 [63].

Dendrobium spp. are medicinal plants containing properties with anti-cancer, anti-fatigue, gastric ulcer protective effects, etc. Of all the bacterial endophytes isolated from stems of *Dendrobium* spp. plants, *Bacillus megaterium* exhibited the highest antimicrobial effects [64]. *Acinetobacter guillouiae*, *B. cereus*, *Burkholderia tropica*, *Novosphingobium* sp., *Pseudomonas moraviensis*, *Pseudomonas* sp., *Rahnella aquatilis*, and *Raoultella ornithinolytica*, were isolated from the Cape coast lily (*Crinum macowanii* Baker) bulbs and showed potential for possible drug lead against common pathogenic bacteria [65]. Traditional uses of *C. macowanii* include treating boils, diarrhea, fever, inflammation, respiratory issues, skin rashes, tuberculosis, wounds, and urinary tract issues. Bacterial isolates FjR1 and FjF2 from the Indian coffee plum (*Flacourtia jangomas* (Lour.) Raeusch.) displayed potential antimicrobial activity against pathogenic bacteria [66]. The longevity spinach (*Gynura procumbens* DC.) is a medicinal plant species for treatment of cancer, constipation, fever, kidney diseases, rheumatism, rashes, headache, and viral skin diseases [67,68]. The leaves of *G. procumbens* contain anti-herpes simplex virus, antihyperglycemic, anti-inflammatory, antihyperlipidemic, anti-allergy agent, and antihypertensive properties [68]. Apart from its antihypertensive, glucose-lowering, and anti-inflammatory properties, it is also a source of proteins and peroxidase [69]. *G. procumbens* leaves contain essential oil, flavonoids, miraculin, polyphenols, peroxidase, thaumatin-like proteins, terpenoids, and unsaturated sterols. The screening of endophytic bacteria for the plant growth regulators such as cytokinin were needed as means to explore if these endophytic bacteria can be applied in agriculture [67]. *Acinetobacter calcoaceticus*, *Paenibacillus polymaxa*, and *Pseudomonas resinovorans* were isolated from *G. procumbens* leaves collected in Malaysia [68]. It was also found that broth extracts from *P. resinovorans* and *P. polymaxa* contain cytokinin-like compounds [68].

Acetone extract from kauri booti (*Ajuga bracteosa* Wall ex Benth.) has antibacterial activity against *E. coli* [70]. This plant contains phytochemicals which have anti-inflammatory, astringent, diuretic, and depurative properties, and can be used to treat agues, menorrhoea, bronchitis, diarrhea, fever, gout, jaundice, pneumonia, palsy, and rheumatism [71]. The leaves, bark, stem, and roots of *A. bracteosa* have medicinal properties, can be used as an astringent against hypoglycaemic and gastrointestinal disorders, and have anthelmintic, diuretic, antifungal, anti-inflammatory, and antimycobacterial compounds [71]. Bacterial species were isolated and screened for PGP and biotechnological potential associated with *A. bracteosa*, with most isolates belonged to *Proteobacteria* and *Pseudomonas* [70,71]. These isolates exhibited PGP through production of siderophores and indole acetic acid. They are also capable of phosphate solubilization through production of hydrolytic enzymes such as amylase, cellulase, chitinase, lipase, pectinase, phosphatase, and protease [71].

The biological compounds produced by endophytic bacteria play a pivotal role in the protection of medicinal and herbal plants against pests and pathogens (Table 1). Living plants are a good source for bacterial endophytes which can be isolated for more efficient production of antimicrobial compounds with pharmacological importance. In turn, medicinal plants could also benefit in terms of growth promotion with less application of inputs such as fertilizers, fungicides, insecticides, or herbicides.

Table 1. Endophytic bacteria with antimicrobial activity and associated secondary metabolites from medicinal and herbal plant species.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Host Plant Part/Region	References
<i>Pseudomonas</i> sp., <i>Bacillus</i> sp., <i>Enterobacter</i> sp., <i>Pantoea</i> sp., <i>Chryseobacterium</i> sp., <i>Sphingobacterium</i> sp., <i>Aeromonas</i> sp., <i>Providencia</i> sp., <i>Cedecea</i> sp., <i>Klebsiella</i> sp., <i>Cronobacter</i> sp., <i>Macrococcus</i> sp., <i>Shigella</i> sp.	1,1-diphenyl-2- picrylhydrazyl, ascorbic acid production	<i>Aloe vera</i>	Stem, leaf, root	[72]
<i>Streptomyces</i> sp., <i>Micromonospora</i> sp., <i>Microbiospora</i> sp., <i>Nocardia</i> sp.	Coronamycin, hydroxamate type siderophores production	<i>Azadirachta indica</i>	Stem, leaf, root	[73]
<i>Bacillus</i> sp., <i>Bacillus megaterium</i> , <i>Bacillus pumilus</i> , <i>Bacillus</i> <i>licheniformis</i> , <i>Micrococcus luteus</i> , <i>Paenibacillus</i> sp., <i>Pseudomonas</i> sp., <i>Acinetobacter calcoaceticus</i>	Amylase, esterase, lipase, protease, pectinase, xylanase, and cellulose production	<i>Plectranthus tenuiflorus</i>	Stem, leaf, root	[74]
21 endophytic bacteria	Amines, amides, acids, quinines, indole derivatives, steroids, azoles, alcohols, and hydrocarbons production	<i>Cleodendrum myricoides</i> , <i>Lannea flavus</i> , <i>Dichrostachys cinerea</i> , <i>Gomphocarpus fruticosus</i> , <i>Balanites aegyptica</i> , <i>Jasminum floribundum</i> , <i>Hibiscus fuscus</i>	Root	[75]
<i>Bacillus polyfermenticus</i> , <i>Bacillus</i> <i>subtilis</i> , <i>Bacillus licheniformis</i> , <i>Bacillus pumilus</i>	Cellulase production, Xylanase production, annanase production Pectinase, Amylase, Protease, Lipase, Esterase, DNase, Chitinase production	<i>Codonopsis lanceolata</i>	Root	[76]
<i>Bacillus amyloliquefaciens</i>	diethyl ether, ethyl acetate production	<i>Memecylon edule</i> , <i>Tinospora cordifolia</i> , <i>Phyllodium pulchellum</i> , <i>Dipterocarpus</i> <i>tuberculatus</i>	Whole plant	[77]
<i>Bacillus</i> spp.	NM	<i>Rumex pulcher</i>	Leaf, stem	[78]
<i>Bacillus amyloliquefaciens</i>	diethyl ether; chloroform and ethyl acetate production	<i>Tinospora cordifolia</i> , <i>Phyllodium pulchellum</i> , <i>Dipterocarpus</i> <i>tuberculatus</i>		[77]
<i>Bacillus</i> spp.	NM	<i>Hypericum scabrum</i>	Leaf	[78]
<i>Bacillus licheniformis</i> , <i>Bacillus pumilus</i>	cellulase, xylanase, mannase, pectinase, amylase, protease, lipase, esterase, DNase, linchinase, chitinase production	<i>Platycodon grandiflorum</i>	Root	[79]
<i>Bacillus</i> sp., <i>Paenibacillus</i> sp., <i>Pseudomonas</i> sp., <i>Ralstonia</i> sp., <i>Micrococcus</i> sp., <i>Alcaligenes</i> spp.	Catalase, Amylase, Gelatinase, Lipase, Nitrate Reductase, Dextrose, Fructose, Lactose, Maltose and Sucrose production	<i>Paederia foetida</i>	Leaf, stem	[80]
<i>Streptomyces griseus</i>	p-Aminoacetophenonic acids production	<i>Kandelia candel</i>	NM	[81]

Table 1. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Host Plant Part/Region	References
<i>Serratia marcescens</i>	Oocydin A production	<i>Rhyncholacis penicillata</i>	NM	[82]
<i>Streptomyces</i> spp.	Munumbicins, Munumbicin D production	<i>Kennedia nigricans</i>	NM	[83]
<i>Paenibacillus polymyxa</i>	Fusaricidin A–D production	<i>Arabidopsis thaliana</i> , <i>Canola</i> spp.	NM	[84]
<i>Streptomyces</i> sp.	Coronamycin production	<i>Monstera</i> sp.	NM	[85]
<i>Phyllobacterium</i> sp.	Fatty acids production	<i>Epimedium brevicornum</i>	Stem, root	[86]
<i>Streptomyces</i> sp.	Indolosesquiterpenes, xiamycin, indospene, sespene production	<i>Kandelia candel</i>	Stem	[87]
<i>Streptomyces</i> sp.	Xiamycin production	<i>Bruguiera gymnorrhiza</i>	Stem	[88]
<i>Saccharopolyspora flava</i> , <i>Pseudonocardia zijingensis</i> , <i>Nocardia carnea</i> , <i>Streptomyces hainanensis</i> , <i>Polymorphospora rubra</i> , <i>Janibacter melonis</i> , <i>Nocardiopsis dassonvillei</i> , <i>Glycomyces sambucus</i>	NM	<i>Maytenus austroyunnanensis</i>	Root	[89]
<i>Gordonia sputi</i> , <i>Gordonia polyisoprenivorans</i> , <i>Microbacterium paraoxydans</i> , <i>Nocardiopsis dassonvillei</i> , <i>Jiangella alkaliphila</i> , <i>Tsukamurella tyrosinosolvans</i>	NM	<i>Maytenus austroyunnanensis</i>	Stem	[89]
<i>Saccharopolyspora gregorii</i>	NM	<i>Gloriosa superba</i>	Stem	[89]
<i>Amycolatopsis pretoriensis</i>	NM	<i>Saccharopolyspora gregorii</i>	Root	[89]
<i>Lentzea albida</i>	NM	<i>Ficus tikoua</i>	Root	[89]
<i>Pseudonocardia alni</i>	NM	<i>Callicarpa longifolia</i>	Leaf	[89]
<i>Pseudonocardia kongjuensis</i>	NM	<i>Lobelia clavata</i>	Leaf	[89]
<i>Rhodococcus fascians</i>	NM	<i>Cercidiphyllum japonicum</i>	Leaf	[89]
<i>Micromonospora narashino</i> , <i>Micromonospora peucetia</i> , <i>Promicromonospora aerolata</i> , <i>Arthrobacter mysorens</i> , <i>Actinomadura atramentaria</i> , <i>Nonomuraea candida</i>	NM	<i>Mycobacterium monacense</i>	Leaf	[89]
<i>Dietzia maris</i>	NM	<i>Schima</i> sp.	Stem	[89]
<i>Dietzia natronolimnaea</i>	NM	<i>Cercidiphyllum japonicum</i>	Root	[89]
<i>Streptomyces specialis</i>	NM	<i>Sedum</i> sp.	Root	[89]
<i>Blastococcus aggregatus</i> , <i>Dactylosporangium aurantiacum</i>	NM	<i>Tripterygium wilfordii</i>	Root	[89]
<i>Catellatospora chokoriensis</i>	NM	<i>Berberis chingii</i>	Root	[89]
<i>Kineospora aurantiaca</i> , <i>Saccharopolyspora flava</i>	NM	<i>Tripterygium wilfordii</i>	Stem	[89]
<i>Promicromonospora sukumoe</i>	NM	<i>Cymbopogon citratus</i>	Root	[89]

Table 1. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Host Plant Part/Region	References
<i>Oerskovia jenensis</i>	NM	<i>Ginkgo</i> sp.	Leaf	[89]
<i>Micrococcus flavus</i>	NM	<i>Polyspora axillaris</i>	Root	[89]
<i>Micrococcus flavus</i>	NM	<i>Aquilaria sinensis</i>	Root	[89]
<i>Actinocorallia aurantiaca</i>	NM	<i>Duranta repens</i>	Root	[89]
<i>Actinocorallia herbida</i>	NM	<i>Millettia reticulata</i>	Leaf	[89]
<i>Herbidospora cretacea</i>	NM	<i>Osyris wightiana</i>	Stem	[89]
<i>Glycomyces algeriensis</i>	NM	<i>Carex baccans</i>	Root	[89]
<i>Glycomyces algeriensis</i>	NM	<i>Scoparia dulcis</i>	Root	[89]
Unidentified bacterial endophytes (gram positive)	Amines, amides, acids, quinines, indole derivatives, steroids, azoles, alcohols, hydrocarbons production	<i>Cleodendrum myricoides</i> , <i>Lannea flavus</i> , <i>Dichrostachys cinerea</i> , <i>Gomphocarpus fruticosus</i> , <i>Balanites aegyptica</i> , <i>Jasminium floribundum</i> , <i>Hibiscus fuscus</i>	Root	[89]
<i>Lysinibacillus</i> sp., <i>Paenibacillus</i> sp., <i>Pseudomonas</i> sp., <i>Bacillus</i> sp., <i>Kocuria</i> sp., <i>Streptomyces</i> sp., <i>Providencia</i> sp., <i>Rhizobium</i> sp., <i>Leucobacter</i> sp., <i>Brachybacterium</i> sp., <i>Mycobacterium</i> sp.	fengycins, surfactants production	<i>Polygonum cuspidatum</i>	Root	[55]
<i>Enterobacter</i> sp., <i>B. subtilis</i>	amylase, cellulase, xylanase, mannase, PGAase, DNase, protease, and esterase production	<i>Raphanus sativus</i>	Leaf, root	[55]
<i>Bacillus</i> spp.		<i>Andrographis paniculata</i>	Leaves	[57]
<i>Pseudomonas</i> spp., <i>Serratia</i> sp., <i>Bacillus</i> sp., <i>Arthrobacter</i> sp., <i>Micrococcus</i> sp., <i>Curtobacterium</i> sp.		<i>Piper nigrum</i>	Root, stem	[58]
<i>Bacillus amyloliquefaciens</i>	Bacteriocins production	<i>Bruguiera gymnorrhiza</i>	Leaf	[90]
<i>Bacillus thuringiensis</i> , <i>B. pumilus</i>		<i>Suaeda monoica</i> , <i>Suaeda maritima</i> , <i>Salicornia brachiata</i> , <i>Lummitzera racemosa</i> , <i>Sesuvium portulacastrum</i> , <i>Rhizophora apiculata</i> , <i>Rhizophora mucronata</i> , <i>Bruguiera cylindrica</i> , <i>Ceriops decandra</i> , <i>Avicennia marina</i> , <i>Aegiceras corniculatum</i>	Leaf	[91]
<i>Paenibacillus</i> sp.	Cellulases, xylanases, pectinase, fusaricidin, peptide synthetase, lipopeptides, and bacitracin production	<i>Aloe chinensis</i>	Root	[92]

Table 1. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Host Plant Part/Region	References
<i>Actinomadura</i> sp., <i>Amycolatopsis</i> sp., <i>Dactylosporangium</i> sp., <i>Kocuria</i> sp., <i>Kribbella</i> sp., <i>Micrococcus</i> sp., <i>Micromonospora</i> sp., <i>Nonomuraea</i> sp., <i>Promicromonospora</i> sp., <i>Pseudonocardia</i> sp., <i>Rhodococcus</i> sp., <i>Streptomyces</i> sp., <i>Streptosporangium</i> sp.	Antibiotics production	<i>Artemisia annua</i>	Leaf, stem, root	[93]
<i>Streptomyces</i> sp., <i>Streptosporangium</i> sp., <i>Microbispora</i> sp., <i>Streptovorticillium</i> sp., <i>Sacchromonospora</i> sp., <i>Nocardia</i> sp.	Munumbacin A-D, Kakadumy, Coronamycin production	<i>Azadirachta indica</i>	Leaf, stem, root	[94]
<i>Bacillus</i> sp., <i>Enterobacter</i> sp., <i>Streptomyces</i> sp.	NM	<i>Paeonia ostii</i>	Root	[95]
<i>Pseudomonas aeruginosa</i>	2,4-Dichlorophenoxyacetic acid, 4-chlorophenoxyacetic acid, Phenazone production	<i>Platycodon grandiflorum</i>	Root	[79]
<i>Paenibacillus polymyxa</i> , <i>Bacillus</i> sp., <i>Pseudomonas poae</i>	Cellulase, xylanase, pectinase production	<i>Panax ginseng</i>	Root	[96]
<i>Bacillus amyloliquefaciens</i> subsp. <i>Plantarum</i> , <i>Bacillus methylotrophicus</i>	NM	<i>Panax notoginseng</i>	root, stem, Petiole, leaf, seed	[97]
<i>Bacillus subtilis</i> , <i>Pseudomonas fluorescens</i>	Iturin A, surfactant production	<i>Centella asiatica</i>	Leaf	[98]
<i>Arthrobacter</i> sp., <i>Achromobacter</i> sp., <i>Bacillus</i> sp., <i>Enterobacter</i> sp., <i>Erwinia</i> sp., <i>Pseudomonas</i> sp., <i>Pantoea</i> sp., <i>Serratia</i> sp., <i>Stenotrophomonas</i> sp.	Cellulase, protease, β -1,3-glucanase, hydrogen cyanide production	<i>Hypericum perforatum</i>	Root, stem, leaf	[99]
<i>Achromobacter</i> sp., <i>Bacillus</i> sp., <i>Enterobacter</i> sp., <i>Erwinia</i> sp., <i>Pseudomonas</i> sp., <i>Pantoea</i> sp.	Cellulase, Protease, β -1,3-glucanase, hydrogen cyanide production	<i>Ziziphora capitata</i>	Root, stem, leaf	[99]
<i>Pseudomonas hibiscicola</i> , <i>Macrococcus caseolyticus</i> , <i>Enterobacter ludwigii</i> , <i>Bacillus anthracis</i>	1,1-diphenyl-2-picrylhydrazyl production	<i>Aloe vera</i>	Root, stem, leaf	[72]
<i>B. tequilensis</i> , <i>Pseudomonas entomophila</i> , <i>Chryseobacterium indologenes</i> , <i>B. aerophilus</i>	Ascorbic acid production	<i>Aloe vera</i>	Root, stem, leaf	[72]

NM = not mentioned.

2.2. Growth-Promoting Bacteria on Medicinal and Herbal Plants

Sixty-one bacteria were identified and comparatively characterized from the root nodules of *Medicago*, *Melilotus*, *Onobrychis*, *Oxytropis*, and *Vicia* species grown in the Loess Plateau and Qinghai-Tibet Plateau [100]. *Vicia sativa* has been used as a traditional medicine to treat asthma, bronchitis, skin infections, and urinary diseases, and it also has anti-poison, antiseptic, aphrodisiac, antipyretic, and antirheumatic properties [101]. *Oxytropis* spp. contain flavonoids, alkaloids, and saponins which have medicinal properties [102]. Apigenin, caffeic acid, gallic acid, pyrogallol, salicylic acid, naringenin, quercetin, myricetin, and

daidzein are major secondary metabolites in the extract of the alfalfa (*Medicago sativa* L.) leaves [103]. *Melilotus* spp. are native to the Mediterranean area [104]; their herbs have aromatic, emollient, and carminative properties [105]. *Onobrychis* genus is an important legume with over 150 species [106]. Among the bacterial isolates are *Rhizobium leguminosarum*, *S. meliloti*, and *S. fredii*; the rest belong to *Mesorhizobium*, *Phyllobacterium*, and *Stenotrophomonas*. Species of *R. leguminosarum* was isolated from *Oxytropis* spp. and medick or burclover (*Medicago archiducis-nicolai* Širj.), while *S. fredii* was isolated from the black medick (*Medicago lupulina* L.) grown in the Qinghai-Tibet Plateau. These strains were also found to be resistant to high alkalinity and a high concentration of NaCl [100]. *V. sativa* contains significant activity against pathogenic bacterial species such as *Bacillus atrophaeus*, *E. coli*, *S. aureus*, and *Staphylococcus epidermidis* [101]. *Medicago* spp. are used to treat eczema, anemia, constipation, body odor, infections, burns, athlete's foot, cancer, arthritis, intestinal ulcers, gastritis, liver diseases, bleeding gums, and high blood pressure.

The hyacinth bean (*Lablab purpureus* (L.)) serves as a herbal medicine in China for the treatment of internal heat fever. The leaves and fruits of *L. purpureus* contain sterols and fatty acids such as palmitic, palmitoleic, linoleic, and linolenic acids [104,107,108]. Pyridine alkaloids, trigonelline, and sterols have been isolated from tissue cultures of seeds, stems, and leaves. To study the diverse rhizobia associated with this plant, *Bradyrhizobium*, *Rhizobium*, *Ensifer*, and *Mesorhizobium* species were isolated from southern China [104].

Based on 16S rDNA analysis, the bacteria isolated belonged to *Aeromonas*, *Bacteroides*, *Cytophaga*, *Flexibacter*, *Ilyobacter*, *Pelomonas*, *Proteobacteria*, *Pseudomonas*, *Rhodoferrax*, *Rhizobium*, *Sulfurospirillum*, and *Uliginosibacterium*. These endophytic bacteria have the capacities of fixing nitrogen and removal of contaminants from the water body through phytoremediation by degrading catechol, cyanide, methane, methanol, methylated amines, oxochlorate, urea, and 2,4-Dichlorophenoxyacetic acid [109]. Although this area of study will not form part of our investigation, we may opportunistically assess the possibility of environmental remediation by bacteria when we survey natural populations of *A. phyllicoides*.

Caragana spp. are leguminous plants containing more than 80 species worldwide [110]. The roots, flowers, shoots, barks, and seeds are useful plant parts applied as herbal medicine [111] for the treatment of cancer of gynecological problems [112]. Species of the genus *Caragana* are resistant to extreme temperatures and have nitrogen-fixing abilities [110]. *Agrobacterium*, *Mesorhizobium*, *Rhizobium*, *Bradyrhizobium*, and *Phyllobacterium* species are associated with *Caragana* species grown in China [110].

Bacterial species belonging to Actinobacteria, Bacteroidetes, Firmicutes, and Proteobacteria phyla are salinity tolerant nitrogen-fixing endophytic bacteria isolated from roots of the halophyte *Suaeda* sp. obtained in Iran and are capable of growth-promotion the halophyte sea-blite (*Suaeda maritima* (L.) Dumort.) [113]. Nitrogen-fixing bacteria of *Brachy-bacterium saurashtrense* sp. nov., *Zhihengliuella* sp., *Brevibacterium casei*, *Haererehalobacter* sp., *Halomonas* sp., *Vibrio* sp., *Cronobacter sakazakii*, *Pseudomonas* spp., *Rhizobium radiobacter*, and *Mesorhizobium* sp. were isolated and identified from roots of halophytic pickleweed (*Salicornia brachiata* Miq.) using analysis of 16S rRNA genes. It has been revealed that isolated endophytic bacteria from *S. brachiata* is capable of growth promotion based on production of indole acetic acid production, phosphate solubilization, and 1- aminocyclopropane-1-carboxylic acid deaminase [114].

Using 16 S rDNA, it was discovered that the root nodules of *Mimosa patida* contains *Burkholderia* spp. that secretes phytohormone, aminocyclopropane-1-carboxylic acid deaminase, and solubilizes phosphate and has antimicrobial activity against phytopathogens [115]. *Azotobacter beijerinckii*, *Azotobacter chroococcum*, *Azospirillum lipoferum*, and *Azotobacter vinelandii* isolated from the roots of medicinal aloe (*Aloe vera* (L.) Burm.f.) and devil's trumpet (*Datura metel* L.) fix nitrogen. These isolates also secrete glucose, sucrose, lactose, maltose, rhamnose, xylose, and mannitol. The production of indole acetic acid by *A. beijerinckii*, *A. chroococcum*, and *A. vinelandii* stimulated the growth of *A. vera* and *D. metel* [116].

The root nodules of sulla (*Hedysarum carnosum* L.), clover bord (*Hedysarum spinosissimum* L.), and *Hedysarum pallidum* Desf., sampled from various localities in Algeria, were isolated based on the ARDRA, Random Amplified Polymorphic DNA (RAPD) fingerprinting, and 16S rDNA have, *E. cloacae*, *Enterobacter kobei*, *Escherichia vulneris*, *Leclercia adecarboxylata*, *Pantoea agglomerans* and *Pseudomonas* sp. [117]. *Rhizobium tropici* isolated had nitrogen-fixing symbioses with *Medicago ruthenica* [118]. Both the isolation and characterization of *Rhizobium*, *Sinorhizobium*, *Mesorhizobium*, and *Bradyrhizobium* species from *Acacia*, *Anthyllis*, *Argyrolobium*, *Astragalus*, *Calycotome*, *Coronilla*, *Ebenus*, *Genista*, *Hedysarum*, *Hippocrepis*, *Lathyrus*, *Lotus*, *Medicago*, and *Ononis* species from southern Sudan were based on comparative 16S ARDRA using seven enzymes, total cell protein sodium dodecyl sulphate–polyacrylamide gel electrophoresis (SDS–PAGE) analysis, and 16S rDNA sequencing [119].

Rhizobium huautlense, a nitrogen-fixing rhizobial symbionts of bigpod sesbania (*Sesbania herbacea* (Mill.) McVaugh), sampled at Sierra de Huautla, Mexico, was isolated and identified using PCR–RFLP analysis. The electrophoretic alloenzyme types (Ets) were also identified [120]. *R. indigoferae* sp. nov. and *Sinorhizobium kummerowiae* sp. nov. from root nodules of *Indigofera* spp. and *Kummerowia* spp.; *R. loessense* sp. nov. from the root nodules of *Astragalus* and *Lespedeza* spp; and *R. sullae* sp. nov. were described as the nitrogen-fixing bacterial symbionts [121–123]. The multi-locus enzyme electrophoresis (MLEE) and 16S rRNA gene sequence analysis revealed two nitrogen fixing bacterial species of *Sinorhizobium arboris* sp. nov. and *Sinorhizobium kostiense* sp. nov. from the root nodules of *Acacia rutico* and *Prosopis chilensis* sampled in Sudan and Kenya [124].

Sinorhizobium morelense sp. nov. isolated from root nodules of jumbay (*Leucaena leucocephala* (Lam.) de Wit) has been found to be resistant to carbenicillin, kanamycin, and erythromycin [125]. This medicinal plant is frequently used to treat diabetes. It is also used to treat stomach ailments, assist abortion, and promote contraction. The revealed *Allorhizobium undicola* sp. nov. isolated from the water mimosa or sensitive Neptunia (*Neptunia natans* (Girard) Kuntze) based on the 16S rRNA gene sequencing has nitrogen-fixing ability [126]. This medicinal plant has pharmacological qualities that include antifungal, antiemetic, astringent, anthelmintic, antidysentery, diuretic, anti-inflammatory, antioxidant, hypercholesterolemia, antipyretic, and antiemetic properties.

From nodules of False Indigo (*Amorpha fruticosa* L.), *M. amorphae* sp. nov. was characterized based on the RFLP of PCR-amplified 16S rRNA genes, MLEE, DNA–DNA hybridization, 16S rRNA gene sequencing, electrophoretic plasmid profiles, cross-nodulation, and a phenotypic study [127]. *A. fruticosa* is used to treat dermatitis, carbuncles, and burns in traditional Chinese medicine. DNA–DNA hybridizations were conducted to identify *Mesorhizobium* spp. from the sample from the white carob tree (*Prosopis alba* Griseb.) root nodules grown in Argentina [128]. *R. tropici* were found to be root modulating bacteria of *N. natans* from India [129]. *Prosopis* plants have a variety of bioactive qualities, including antioxidant, anti-inflammatory, anti-cancer, and anti-diabetic properties.

A new species name for a root-forming nodule bacterial isolate, *Devosia neptuniae* sp. nov., which was previously classified as *A. undicola*, was suggested to neptunium-modulating rhizobia isolated from India. This bacterial species can form a bonafide dinitrogen-fixing root-nodule symbiosis with other legume plants [130].

Root-nodule isolates of *Bradyrhizobium*, *Mesorhizobium*, *Rhizobium*, and *Sinorhizobium* spp. from *Lespedeza* spp., collected from China and the USA, were isolated and characterized using SDS–PAGE analysis of whole-cell proteins, DNA–DNA hybridization, and 16S rRNA gene sequence analysis [131]. *Ralstonia taiwanensis* sp. nov. was isolated from *Mimosa* spp. and is the capable of root nodule formation and nitrogen fixation [132].

The endophytic bacterial isolates from *H. carnosum*, *H. spinosissimum* subsp. *capitatum*, and *H. pallidum* grown in Algeria were identified as *P. agglomerans*, *E. kobei*, *E. cloacae*, *L. adecarboxylata*, *E. vulneris*, and *Pseudomonas* sp. by means of ARDRA using the enzyme Cfo I, RAPD fingerprinting and sequencing of 16S rDNA. This was the first report confirming that Gammaproteobacteria is associated with *H. carnosum*, *H. spinosissimum* subsp. *Capitatum*, and *H. pallidu* [117]. The diversity of endophytic bacteria from the root of *Angelica sinensis*

in Angelica in the Gansu province revealed that certain endophytic bacterial strains may have come from the rooting zone [133].

Among the endophytic bacteria isolated from the red clover (*Trifolium pratense* L.), *P. agglomerans* (59.6%) was mostly detected in foliage tissues, *Agrobacterium rhizogenes* A in the tap root (49.2%), and *R. leguminosarum* BV *phaseoli* and *R. loti* B in the nodules (27.2% each) [134]. In addition, *T. pratense* has been used medicinally to treat a number of illnesses, such as eczema and psoriasis, cancer, whooping cough, respiratory issues, and skin inflammations. *B. megaterium*, *Bordetella avium*, *Curtobacterium luteum*, and *R. leguminosarum* BV *trifolii* promoted the growth of *T. pratense*. Nodulation of red clover seedlings became evident because of co-inoculation of *R. leguminosarum* BV *trifolii* with *Bacillus insolitus*, *B. brevis*, or *A. rhizogenes* A [134]. Crop rotations of *T. pratense* and potato (*Solanum tuberosum* L.) have specific associations with bacterial endophytes. Of all the growth-promoting bacterial strains isolated from these plants, 63% enhanced shoot height, 66% enhanced shoot wet weight, and 55% enhanced root wet weight [135]. It has been claimed that potatoes offer a multitude of medicinal properties, including antioxidant, anticancer, antiallergy, antibacterial, anti-inflammatory, anti-obesity, and anti-ulcer action. A total of 200 bacterial isolates from the berseem clover (*Trifolium alexandrinum* L.) possess plant growth promoting traits. Production of indole acetic acid by the endophytic bacteria stimulated the plant development of rice plant [136]. Because of their expectorant, analgesic, and antibacterial qualities, *Trifolium* spp. are also used to treat rheumatic pains. Co-inoculation of *T. repens* with *Rhizobium* strains CHB1120 and CHB1121, *Bacillus aryabhatai* strain Sb, and *A. vinelandii* strain G31 promotes the nitrogen fixation and nutrient uptake of white clover in a P-deficient soil [137].

Nitrogen-fixing bacteria can form endophytic colonies in various medicinal and herbal plants. These beneficial bacteria fix nitrogen from the atmosphere to enhance the length and biomass of medicinal and herbal plants. Nitrogen-fixing endophytic bacteria may be useful for the sustainable production of medicinal and herbal plants, specifically in saline-based environments. Nitrogen-fixing bacteria are currently being introduced as biofertilizers.

Native phosphate-solubilizing endophytic bacteria, including those from rhizospheres, improve the growth of herbal and medicinal plants. Various leaf structural and chemical characteristics were assessed as possible predictors of the size of the phyllosphere bacterial population associated with plant species such as strawberry tree (*Arbutus unedo* L. 1753), lesser calamint (*Calamintha nepeta* (L.) Kuntze), rockrose (*Cistus × incanus* L.), lavender (*Lavandula stoechas* L.), lemon balm (*Melissa officinalis* L.), common myrtle (*Myrtus communis* L.), lentisk or mastic (*Pistacia lentiscus* L.), and kermes oak (*Quercus coccifera* L.) [57]. *A. unedo* contain polyphenols, which are reported to manage cancer risk, coronary heart disease, and other degenerative diseases [58]. *Quercus* spp. have been used as traditional medicinal plants and are antiseptic and hemostatic for the treatment of diarrhea and hemorrhoids [59]. Certain species of the genus *Quercus* contain antimicrobial, anti-inflammatory, gastroprotective, antioxidant, cytotoxic, and antitumor properties [59]. The extract of the different parts of *P. lentiscus* has antiatherogenic, anti-inflammatory, antioxidant, antimicrobial, hypotensive, anticancer, anti-arthritis, antigout, anti-asthmatic, and anthelmintic activities [60]. *M. communis* is used for various ailments such as diarrhea, dysentery, gastric ulcers, hemorrhages, leucorrhea, rheumatism, sinuses, and vomiting [61]. Lavender oils are derived from the true lavender (*Lavandula angustifolia* Mill.), Spanish lavender (*Lavandula stoechas* L.), broadleaved lavender (*Lavandula latifolia* Medik.) and lavender (*Lavandula × intermedia* ‘Grosso’) [62], which have antimicrobial, anti-inflammatory, hypnotic, and anxiolytic properties [63]. *C. × incanus* contains phenolic substances together with an associated strong antioxidant activity [64]. *C. nepeta* is aromatic, diaphoretic, expectorant, febrifuge, and stomachic [65]. *M. officinalis* possesses antioxidants such as caffeic and rosmarinic acids [66]. *M. officinalis* also contains antibacterial and antiviral properties. The role of the P-solubilizing bacterium *Enterobacter ludwigii* in the growth promotion and P content of barley (*Hordeum vulgare* L.) was investigated [138].

The study revealed beneficial effects on the dry weight, P assimilation, and barley yield in *E. ludwigii*-inoculated plants [138]. *C. nepeta*, *M. communis*, *M. officinalis*, and *L. stoechas* produce essential oils. Interestingly, aromatic plants are more colonized than the other species, whereas the non-woody perennials are more highly colonized than the water pepper (*Polygonum hydropiper* (L.) Delabre 1800) is regarded as a P-accumulating herb used for P-phytoextraction, with higher P-accumulating capability in the mining ecotype compared to the non-mining ecotype [139]. In traditional medical systems, water pepper is used as an astringent, sedative, antiseptic, and to treat respiratory problems, edema, and snake bites.

Tea plant (*Camellia sinensis* (L.) Kuntze) is used in one of the most important beverages; the plant contains about 4000 bioactive compounds, of which 1/3 is contributed by polyphenols alone [140]. The phytochemical screening of green tea showed the presence of alkaloids, saponins, tannins, catechin, and polyphenols [56,141], which are quality parameters of tea. A study was conducted to examine the diversity of cultivable P-solubilizing bacteria in *C. sinensis* [142]. Over 900 rhizoplane bacteria were randomly selected and were identified using fatty acid methyl ester (FAME) analysis and isolates belonging to *Bacillus* (34.6%), *Pseudomonas* (8.9%), *Stenotrophomonas* (6.1%), *Paenibacillus* (5.9%), and *Arthrobacter* (4.8%) were identified [2]. The leaf of *C. sinensis* showed antimicrobial properties against *S. aureus*, *Vibrio cholerae*, *C. jejuni*, *S. epidermidis*, *V. mimicus*, *L. monocytogenes*, *E. coli*, *S. typhi*, *P. aeruginosa*, *H. pylori*, and *P. acnes*, among others [143–152]. *Proteobacteria* and *Sphingobacteria* spp. possess plant growth promoting attributes such as indole acetic acid, aminocyclopropane-1-carboxylic acid deaminase production, and P and K-solubilization [153].

Aloe (*Aloe barbadensis* Mill.) is an important medicinal plant with applications in pharmaceutical, food, and cosmetic industries and is used for flavoring liquid formulations [154]. *A. barbadensis* contains phenolic compounds such as aloin-A (barbaloin), aloesin, soaloeresin D, and aloeresin E used in the treatment of tumors, diabetes, ulcers, and cancer [155]. *Burkholderia gladioli*, *Enterobacter hormaechei*, *Pseudomonas synxantha*, and *S. marcescens* isolated from *A. barbadensis* are capable of solubilizing phosphate into liquid phase [154]. From *Brassica juncea* (L.) Czern and Coss var. Pusa Bold (DIR-50), a Ni-tolerant *B. subtilis* strain SJ-101 was isolated and identified. It was found that the strain SJ-101 produced indole acetic acid and solubilized inorganic phosphate [55]. Endophytic bacteria isolate from *P. hydropiper* contains plant growth promotion traits including indole acetic acid, siderophores, and phosphate-solubilization among others [156]. Endophytic bacterial strains isolated from the tissues of livening thyme (*Thymus vulgaris* L.) exhibited some plant growth-promoting activities such as auxin synthesis, diazotrophic, P-solubilization, siderophore production, and production of lytic enzymes (i.e., chitinase, cellulase, protease, and lipase) under in vitro conditions [157]. *T. vulgaris* has been used for treating chest congestion and promoting salivation since ancient times. The fresh leaves are also consumed to soothe sore throats.

Endophytic bacteria are capable of solubilizing inorganic phosphate in a solid medium, thereby increasing its availability to living medicinal and herbal plants (Table 2). Phytochemicals released by endophytic bacteria promote the sustainable production of medicinal and herbal plants resulting from improved fertility of the soil, and hence increase medicinal and herbal plant production.

Table 2. Growth-promoting bacteria and associated secondary metabolites from medicinal and herbal plant species.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Host Plant Part/Region	References
<i>Enterobacter</i> sp. strain 638, <i>Stenotrophomonas maltophilia</i> R551-3, <i>Pseudomonas putida</i> W619, <i>Serratia proteamaculans</i> 568	Root/ biomass development	<i>Populus</i> spp.	Root and shoot	[158]

Table 2. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Host Plant Part/Region	References
<i>Bradyrhizobium</i> sp.	Increased Nitrogen and phosphorus uptake	<i>Cicer arietinum</i>	Root	[159]
<i>Mesorhizobium ciceri</i>	Increased Nitrogen and phosphorus uptake	<i>Vigna radiata</i>	Root	[160]
<i>Rhizobium</i> sp.	Indole acetic acid	<i>Cajanus cajan</i>	Root	[161]
<i>Bradyrhizobium</i> sp.	Increased uptake of P, N and Mg High chlorophyll content	<i>Vigna radiata</i>	Root	[162]
<i>Methylobacterium</i> sp.	NM	<i>Crotalaria glaucoides</i>	Root	[163]
<i>Azotobacter</i> sp., <i>Azospirillum</i> sp.	indole acetic acid production	<i>Aloe vera</i>	Root	[164]
<i>Pantoea agglomerans</i> , <i>Enterobacter kobei</i> , <i>Enterobacter cloacae</i> , <i>Leclercia adecarboxylata</i> , <i>Escherichia vulneris</i>	NM	<i>Hedysarum carnosum</i> , <i>H. spinosissimum</i> subsp. <i>capitatum</i> , <i>H. pallidum</i>	Root	[117]
<i>Rhizobium leguminosarum</i>	NM	<i>Pisum sativum</i> , <i>Vicia</i> sp., <i>Lathyrus</i> sp., <i>Lens</i> sp., <i>Trifolium pratense</i> , <i>Trifolium</i> spp., <i>Phaseolus vulgaris</i> , <i>P. angustifolius</i> , <i>P. multiflorus</i>	NM	[165]
<i>R. elti</i> biovar <i>phaseoli</i>	NM	<i>Phaseolus vulgaris</i> , <i>Leucaena</i> sp.	NM	[166]
<i>R. etli</i> biovar <i>mimosae</i>	NM	<i>Mimosa affinis</i>	NM	[167]
<i>R. hainanense</i>	NM	<i>Desmodium sinuatum</i> , <i>Desmodium gyroides</i> , <i>Desmodium triquetrum</i> , <i>Desmodium heterophyllum</i> , <i>Acacia sinicus</i> , <i>Arachis hypogaea</i> , <i>Centrosema pubescens</i> , <i>Macroptilium lathyroides</i> , <i>Stylosanthes guianensis</i> , <i>Tephrosia candida</i> , <i>Uraria crinita</i> , <i>Zornia diphylla</i>	NM	[168]
<i>R. gallicum</i> biovar <i>gallicum</i>	NM	<i>Phaseolus vulgaris</i> , <i>Leucaena leucocephala</i> , <i>Macroptilium atropurpureum</i> , <i>Onobrychis viciifolia</i>	NM	[168]
<i>R. gallicum</i> biovar <i>phaseoli</i>	NM	<i>Phaseolus vulgaris</i>	NM	[168]
<i>R. mongolense</i>	NM	<i>Medicago ruthenica</i> , <i>Phaseolus vulgaris</i>	NM	[168]
<i>R. galegae</i> biovar <i>orientalis</i>	NM	<i>Galega orientalis</i>	NM	[168]
<i>R. galegae</i> biovar <i>officinalis</i>	NM	<i>Galega officinalis</i> , <i>Astragalus cruciatus</i> , <i>Argyrolobium uniflorum</i> , <i>Anthyllis henoniana</i> , <i>Lotus creticus</i> , <i>Medicago</i> spp.	Root	[168]

Table 2. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Host Plant Part/Region	References
<i>R. giardinii</i> biovar <i>giardinii</i>	NM	<i>Leucaena leucocephala</i> , <i>Macroptilium atropurpureum</i>	NM	[168]
<i>R. giardinii</i> biovar <i>phaseoli</i>	NM	<i>Phaseolus vulgaris</i>	NM	[168]
<i>R. huautlense</i>	NM	<i>Sesbania herbacea</i>	NM	[168]
<i>R. indigoferae</i>	NM	<i>Indigofera amblyantha</i> , <i>I. carlesii</i> , <i>I. potanini</i>	NM	[168]
<i>R. sullae</i>	NM	<i>Hedysarum coronarium</i>	NM	[168]
<i>R. loessense</i>	NM	<i>Astragalus</i> sp., <i>Lespedeza</i> sp.	NM	[168]
<i>R. yanglingense</i>	NM	<i>Coronilla varia</i> , <i>Amphicarpaea trisperma</i> , <i>Gueldenstaedtia multiflora</i>	NM	[168]
<i>Sinorhizobium meliloti</i>	NM	<i>Medicago</i> sp., <i>Melilotus</i> sp., <i>Trigonella</i> sp.	NM	[168]
<i>S. sahelense</i>	NM	<i>Sesbania</i> sp., <i>Acacia</i> sp.	NM	[168]
<i>S. terangae</i>	NM	<i>Acacia</i> sp., <i>Sesbania</i> sp.	NM	[168]
<i>S. medicae</i>	NM	<i>Medicago</i> sp.	NM	[168]
<i>S. kostiense</i>	NM	<i>Acacia</i> sp., <i>Prosopis</i> sp.	NM	[168]
<i>S. morelense</i>	NM	<i>Leucaena leucocephala</i>	NM	[168]
<i>S. americanum</i>	NM	<i>Acacia</i> sp.	NM	[168]
<i>S. arboris</i>	NM	<i>Acacia</i> sp., <i>Prosopis</i> sp.	NM	[168]
<i>S. kummerowiae</i>	NM	<i>Kummerowia stipulacea</i>	NM	[168]
<i>Ensifer adhaerens</i>	NM	<i>Sesbania</i> sp., <i>Medicago</i> sp., <i>Sesbania grandiflora</i> , <i>Leucaena leucocephala</i> , <i>Pithecellobium dulce</i> , <i>Medicagosativa</i> sp.	NM	[168]
<i>Allorhizobium undicola</i>	NM	<i>Neptunia natans</i> , <i>Acacia senegal</i> , <i>A. seyal</i> , <i>A. tortilis</i> , <i>Lotus arabicus</i> , <i>Faidherbia albida</i>	NM	[168]
<i>Mesorhizobium loti</i>	NM	<i>Lotus corniculatus</i> , <i>L. tenuis</i> , <i>L. japonicum</i> , <i>L. krylovii</i> , <i>L. filicalius</i> , <i>L. schoelleri</i> , <i>Anthyllis</i> spp., <i>Lupinus</i> spp.	NM	[168]
<i>M. huakuii</i>	NM	<i>Astragalus sinicus</i> , <i>Acacia</i> spp.	NM	[168]
<i>M. ciceri</i>	NM	<i>Cicer arietinum</i>	NM	[168]
<i>M. tianshanense</i>	NM	<i>Glycyrrhiza pallidiflora</i> , <i>G. uralensis</i> , <i>Sophora alopecuroides</i> , <i>Glycine max</i> , <i>Swainsonia salsula</i> , <i>Halimodendron holodendron</i> , <i>Caragana polourensis</i>	NM	[168]

Table 2. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Host Plant Part/Region	References
<i>M. mediterraneum</i>	NM	<i>Cicer arietinum</i>	NM	[168]
<i>M. plurifarum</i>	NM	<i>Acacia senegal</i> , <i>A. seyal</i> , <i>A. tortilis</i> , <i>Leucaena leucocephala</i> , <i>L. diversifolia</i> , <i>Prosopis juliflora</i> , <i>Chamaecrista ensiformis</i>	NM	[168]
<i>M. amorphae</i>	NM	<i>Amorpha fruticosa</i>	NM	[168]
<i>M. chacoense</i>	NM	<i>Prosopis alba</i>	NM	[168]
<i>Methylobacterium nodulans</i>	NM	<i>Crotalaria podocarpa</i> , <i>C. Perottetti</i> , <i>C. glaucoides</i> .	NM	[168]
<i>Ochrobactrum</i> spp.	NM	<i>A. mangium</i> , <i>Faidherbia albida</i> , <i>Paraserianthes falcata</i>	NM	[168]
<i>Devosia neptuniae</i>	NM	<i>Neptunia natans</i>	NM	[168]
<i>Azorhizobium caulinodans</i>	NM	<i>Sesbania rostrata</i>	NM	[168]
<i>A. johannense</i>	NM	<i>Sesbania virgata</i>	NM	[168]
<i>Azorhizobium</i> sp.	NM	<i>Sesbania rostrata</i>	NM	[168]
<i>Bradyrhizobium japonicum</i>	NM	<i>Glycine max</i> , <i>Glycine soja</i> , <i>Macroptilium atropurpureum</i>	NM	[168]
<i>B. elkanii</i>	NM	<i>Glycine max</i> , <i>Vigna</i> spp., <i>Macroptilium atropurpureum</i>	NM	[168]
<i>B. liaoningense</i>	NM	<i>Glycine max</i> , <i>Glycine soja</i>	NM	[168]
<i>B. yuanmingense</i>	NM	<i>Lespedeza cuneata</i>	NM	[168]
<i>B. betae</i>	NM	<i>Beta vulgaris</i>	NM	[168]
<i>B. canariense</i>	NM	<i>Genisteae</i> and <i>Loteae</i> plants	NM	[168]
<i>Bradyrhizobium</i> sp.	NM	<i>Lupinus</i> spp., <i>Mimosa</i> spp., <i>Faidherbia</i> spp., <i>Acacia</i> spp., 27 herb legumes	NM	[168]
<i>Blastobacter denitrificans</i>	NM	<i>Aeschynomene indica</i>	NM	[168]
<i>Burkholderia caribensis</i>	NM	<i>Mimosa pudica</i> , <i>M. diplotricha</i>	NM	[168]
<i>B. tuberum</i>	NM	<i>Alysicarpus glumaceus</i>	NM	[168]
<i>B. phymatum</i>	NM	<i>Aspalatus carnosa</i> <i>Machaerium lunatum</i>	NM	[168]
<i>Ralstonia taiwanensis</i>	NM	<i>Mimosa pudica</i> , <i>M. diplotricha</i> .	NM	[168]
<i>Pantoea agglomerans</i>	NM	<i>Hedysarum carnosum</i> , <i>H. spinosissimum</i> subsp. <i>capitatum</i> , <i>H. pallidum</i>	NM	[168]
<i>Enterobacter kobei</i>	NM	<i>Hedysarum carnosum</i> , <i>H. spinosissimum</i> subsp. <i>capitatum</i> , <i>H. pallidum</i>	NM	[168]

Table 2. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Host Plant Part/Region	References
<i>Enterobacter cloacae</i>	NM	<i>Hedysarum carnosum</i> , <i>H. spinosissimum</i> subsp. <i>capitatum</i> , <i>H. pallidum</i>	NM	[168]
<i>Leclercia adecarboxylata</i>	NM	<i>Hedysarum carnosum</i> , <i>H. spinosissimum</i> subsp. <i>capitatum</i> , <i>H. pallidum</i>	NM	[168]
<i>Escherichia vulneris</i>	NM	<i>Hedysarum carnosum</i> , <i>H. spinosissimum</i> subsp. <i>capitatum</i> , <i>H. pallidum</i>	NM	[168]
<i>Pseudomonas</i> sp.	NM	<i>Hedysarum carnosum</i> , <i>H. spinosissimum</i> subsp. <i>capitatum</i> , <i>H. pallidum</i>	NM	[168]
<i>Pseudomonas</i> sp.	Indole acetic acid, hydrogen cyanide, and siderophore production	<i>Solanum</i> sp.	Rhizosphere	[169]
<i>Enterobacter aerogenes</i> NBRI K24, <i>Rahnella aquatilis</i> NBRI K3	Aminocyclopropane-1-carboxylic acid deaminase, indole acetic acid, siderophore production	<i>Brassica juncea</i>	NM	[170]
<i>Enterobacter</i> sp.	Aminocyclopropane-1-carboxylic acid deaminase, indole acetic acid, siderophore production	<i>Brassica juncea</i>	NM	[170]
<i>Pseudomonas aeruginosa</i>	Aminocyclopropane-1-carboxylic acid deaminase, indole acetic acid, siderophore production	<i>Solanum nigrum</i>	NM	[171]
<i>Bacillus thuringiensis</i> GDB-1	Aminocyclopropane-1-carboxylic acid deaminase, indole acetic acid, Siderophores, Phosphate solubilization	<i>Alnus firma</i>	Root, shoot	[172]
<i>B. pumilus</i> E2S2, <i>Bacillus</i> sp. E1S2	indole acetic acid, ACC deaminase, siderophores, phosphate solubilization	<i>Sedum plumbizincicola</i>	Root, shoot	[172]
<i>Pseudomonas tolaasii</i> ACC23, <i>P. fluorescens</i> ACC9	ACC deaminase, siderophores indole acetic acid production	<i>B. napus</i>	Root, shoot	[172]
<i>Pseudomonas veronii</i>	indole acetic acid, decrease soil pH, supply P, and Fe	<i>S. alfredii</i>	Root, shoot	[172]
<i>Rhizobium indigoferae</i> sp. nov. and <i>Sinorhizobium kummerowiae</i> sp.	NM	<i>Indigofera</i> spp. and <i>Kummerowia stipulacea</i>	Root	[121]
<i>Achromobacter xylosoxidans</i> Ax10	Aminocyclopropane-1-carboxylic acid deaminase, indole acetic acid production; P solubilization	<i>B. Juncea</i>	Root, shoot	[172]
<i>Psychrobacter</i> sp. SRA1, <i>Bacillus cereus</i> SRA10	Aminocyclopropane-1-carboxylic acid deaminase indole acetic acid, P solubilization	<i>B. Juncea</i>	Root, shoot	[172]

Table 2. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Host Plant Part/Region	References
<i>Pseudomonas</i> sp. SRI2, <i>Psychrobacter</i> sp. SRS8, <i>Bacillus</i> sp. SN9	Aminocyclopropane-1-carboxylic acid deaminase, indole acetic acid production; P solubilization,	<i>B. Juncea</i>	Root, shoot	[172]
<i>Pseudomonas</i> sp. SRI2, <i>Psychrobacter</i> sp. SRS8, <i>Bacillus</i> sp. SN9	Aminocyclopropane-1-carboxylic acid deaminase indole acetic acid production; P solubilization	<i>Brassica oxyrrhina</i>	Root, shoot	[172]
<i>Bacillus subtilis</i> , <i>B. cereus</i> , <i>B. megaterium</i> , <i>Pseudomonas aeruginosa</i>	Improve plant growth and root elongation	<i>Orychophragmus violaceus</i>	Root, shoot	[172]
<i>Pantoea agglomerans</i> Jp3-3, <i>Pseudomonas thivervalensis</i> Y1-3-9	Indole acetic acid, siderophores, Aminocyclopropane-1-carboxylic acid deaminase production; phosphate solubilization	<i>B. napus</i>	Root, shoot	[172]
<i>Enterobacter</i> sp. JYX7, <i>Klebsiella</i> sp. JYX10	Indole acetic acid, siderophores, Aminocyclopropane-1-carboxylic acid deaminase production, phosphate solubilization	<i>Polygonum pubescens</i>	Root, shoot	[172]
<i>Rahnella</i> sp.	Indole acetic acid, siderophores, Aminocyclopropane-1-carboxylic acid deaminase production; phosphate solubilization	<i>Amaranthus hypochondriacus</i> , <i>A. mangostanus</i> , <i>Solanum nigrum</i>	Root, shoot	[172]
<i>Kluyvera ascorbata</i> SUD165	Increased biomass; Aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica napus</i>	NM	[172]
<i>K. ascorbata</i> SUD165, SUD165/26	Increased biomass; Aminocyclopropane-1-carboxylic acid deaminase, siderophores production	<i>Brassica juncea</i>	NM	[172]
<i>Enterobacter cloacae</i> CAL2	Increased biomass; Aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica napus</i>	<i>Enterobacter cloacae</i> CAL2	[172]
<i>B. subtilis</i> SJ-101	Indole acetic acid production; phosphate solubilization	<i>Brassica juncea</i>	NM	[172]
<i>Enterobacter</i> sp. NBRI K28	Increased biomass; indole acetic acid, siderophores, Aminocyclopropane-1-carboxylic acid deaminase production; phosphate solubilization	<i>Brassica juncea</i>	NM	[172]

Table 2. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Host Plant Part/Region	References
<i>Bacillus</i> sp. J119	Increased biomass, indole acetic acid, siderophores production; biosurfactant production	<i>Brassica napus</i>	NM	[172]
<i>P. aeruginosa</i> MKRh3	Increased biomass and rooting, indole acetic acid, siderophores, aminocyclopropane-1-carboxylic acid deaminase production; phosphate solubilization	<i>Vigna mungo</i>	NM	[172]
<i>Bacillus</i> sp. J119	I indole acetic acid, siderophores production; biosurfactant production	<i>Brassica napus</i>	NM	[172]
<i>Pseudomonas</i> sp. M6, <i>Pseudomonas jessenii</i> M15	Increased biomass; indole acetic acid, aminocyclopropane-1-carboxylic acid deaminase production; phosphate solubilization	<i>Ricinus communis</i>	NM	[172]
<i>Achromobacter xylosoxidans</i> Ax10	Increased root and shoot length and biomass; aminocyclopropane-1-carboxylic acid deaminase production; phosphate solubilization, indole acetic acid production	<i>Brassica juncea</i>	NM	[172]
<i>Enterobacter aerogenes</i> , <i>Rahnella aquatilis</i>	Increased biomass and metal uptake; indole acetic acid, siderophores, aminocyclopropane-1-carboxylic acid deaminase production, phosphate solubilization	<i>Brassica juncea</i>	NM	[172]
<i>B. subtilis</i> SJ-101	indole acetic acid, P solubilization	<i>Brassica juncea</i>	NM	[172]
<i>P. putida</i> ARB86	Increased biomass and chlorophyll content	<i>Arabidopsis thaliana</i>	NM	[172]
<i>Bradyrhizobium</i> sp. RM8	Increased growth, seed yield, seed protein, nodule number, plant nutrition, indole acetic acid, siderophores, hydrogen cyanide, ammonia production	<i>Vigna mungo</i>	NM	[172]
<i>Rhizobium</i> sp. RP5	Increased biomass, nodule number and plant nutrition, indole acetic acid, siderophores production	<i>Pisum sativum</i>	NM	[172]

Table 2. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Host Plant Part/Region	References
<i>Enterobacter</i> sp. NBRI K28	Increased biomass, protein, and chlorophyll content, indole acetic acid, siderophores, Aminocyclopropane-1-carboxylic acid deaminase production; P solubilization	<i>Brassica juncea</i>	NM	[172]
<i>Pseudomonas</i> sp. 29C, <i>Bacillus</i> sp. 4C	Increased biomass; indole acetic acid, siderophores production, Aminocyclopropane-1-carboxylic acid deaminase, P solubilization	<i>Brassica juncea</i>	NM	[172]
<i>Pseudomonas</i> sp. M6, <i>Pseudomonas jessenii</i> M15	Increased biomass; indole acetic acid, aminocyclopropane-1-carboxylic acid deaminase production; P solubilization	<i>Ricinus communis</i>	NM	[172]
<i>Pseudomonas</i> sp.	Increased biomass; siderophores production	<i>Cicer arietinum</i>	NM	[172]
<i>Enterobacter erogenes</i> , <i>Rahnella aquatilis</i>	Increased biomass, indole acetic acid, siderophores, aminocyclopropane-1-carboxylic acid deaminase production, P solubilization	<i>Brassica juncea</i>	NM	[172]
<i>Psychrobacter</i> sp. SRA1 and SRA2, <i>Bacillus cereus</i> SRA10	Increased biomass, indole acetic acid, siderophores, aminocyclopropane-1-carboxylic acid deaminase production. P solubilization	<i>Brassica juncea</i> , <i>B. oxyrrhina</i>	NM	[172]
<i>Rahnella</i> sp. JN6	Indole acetic acid, aminocyclopropane-1-carboxylic acid deaminase, siderophores, phosphate solubilization	<i>B. napus</i>	Root, shoot	[172]
<i>Psuedomonas aspleni</i>	Increased biomass; indole acetic acid production	<i>Brassica napus</i>	NM	[172]
<i>Variovorax paradoxus</i> , <i>Rhodoccus</i> sp., <i>Flavobacterium</i> sp.	Increased root length; indole acetic acid, siderophores, production Aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica juncea</i>	NM	[172]
<i>Pseudomonas fluorescens</i> , <i>P. putida</i>	Increased seed germination and growth	<i>Brassica napus</i>	NM	[172]
<i>P. putida</i> UW4, <i>P. putida</i> HS-2	Increased biomass in the field; indole acetic acid, Aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica napus</i>	NM	[172]

Table 2. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Host Plant Part/Region	References
<i>Sinorhizobium</i> sp. Pb002	Aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica juncea</i>	NM	[172]
<i>Azotobacter chroococcum</i> HKN-5, <i>B. megaterium</i> HKP-1, <i>B. mucilaginosus</i> HKK-1	Increased biomass	<i>Brassica juncea</i>	NM	[172]
<i>Pseudomonas</i> sp. RJ10, <i>Bacillus</i> sp. RJ16	Increased biomass; indole acetic acid production	<i>Brassica napus</i>	NM	[172]
<i>Mesorhizobium huakuii</i> subsp. <i>rengei</i> B3	Phytochelatin and metallothionein production	<i>Astragalus sinicus</i>	NM	[172]
<i>Burkholderia cepacia</i>	Increased biomass	<i>Sedum alfredii</i>	NM	[172]
<i>P. putida</i> ARB86	Increased biomass and chlorophyll content	<i>Arabidopsis thaliana</i>	NM	[172]
<i>P. putida</i> HS-2	Increased seed germination and biomass; siderophores, indole acetic acid, aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica napus</i>	NM	[172]
<i>Pseudomonas</i> sp. 29C, <i>Bacillus</i> sp. 4C	Increased biomass; indole acetic acid, siderophores, aminocyclopropane-1-carboxylic acid deaminase production; phosphate solubilization	<i>Brassica juncea</i>	NM	[172]
<i>Proteus vulgaris</i> KNP3	Increased germination, biomass, and chlorophyll	<i>Cajanus cajan</i>	NM	[172]
<i>Pseudomonas</i> sp.	Increased biomass siderophores production	<i>Cicer arietinum</i>	NM	[172]
<i>P. fluorescens</i> G10, <i>Microbacterium</i> sp. G16	Increased biomass; indole acetic acid, siderophores, aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica napus</i>	NM	[172]
<i>Bacillus edaphicus</i> NBT	Increased biomass; indole acetic acid, siderophores, aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica juncea</i>	NM	[172]
<i>Flavobacterium</i> sp.	Increased root length, biomass	<i>Orychophragmus violaceus</i>	NM	[172]
<i>Kluyvera ascorbata</i> SSUD165	Increased biomass; aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica napus</i>	NM	[172]
<i>K. ascorbata</i> SUD165, SUD165/26	Increased biomass; aminocyclopropane-1-carboxylic acid deaminase, siderophores production	<i>Brassica napus</i>	NM	[172]
<i>P. fluorescens</i> , <i>P. putida</i>	Increased seed germination and growth	<i>Brassica napus</i>	NM	[172]

Table 2. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Host Plant Part/Region	References
<i>P. putida</i> HS-2	Increased seed germination and biomass; siderophores, indole acetic acid, aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica napus</i>	NM	[172]
Different endophytic bacteria	Na ⁺ /K ⁺ accumulation	<i>Salicornia</i> , <i>Arthrocnemum</i> , <i>Haloxylon</i> , <i>Sesuvium</i> , <i>Suaeda</i> , <i>Aeluropus</i> , <i>Heleochloa</i> , <i>Atriplex</i> , and <i>Salvadoraet</i>	shoot and root	[173]
<i>Pseudoalteromonas maricaloris</i>	1-aminocyclopropane-1-carboxylic acid Deaminase production	<i>Avicennia marina</i>	Rhizosphere	[174]

NM = not mentioned.

2.3. Endophytic Bacterial Species Responsible for Phytomediation on Medicinal/Herbal Plants

Due to a variety of industrial activities as well as natural processes, the accumulation of heavy metals in soil has rapidly grown. Endophytic bacteria can be isolated from leaves, stems, and roots of plants grown in contaminated soil. Many endophytes are capable of degrading organic contaminants and heavy metals, and can therefore be used for phytoremediation on contaminated soils [175]. The mobility and bioavailability of heavy metals in the soil influence phytoextraction and phytostabilization [16,155]. Plant tolerance to the contamination is crucial for successful phytoremediation [176]. Decontamination may be accelerated with appropriate microorganisms' inoculation that is able to break down pollutants and compete with indigenous microorganisms.

Yellowtop (*Alyssum murale* Waldst. and amp; Kit.) is regarded as a metal hyperaccumulator plant and is able to solubilize Ni. *A. murale* has been used in combination with other medicinal plants for gynecological disorders. It has also been found that *Microbacterium oxydans* AY509223 increased Ni uptake of *A. murale* [177]. NBRI K28 *Enterobacter* sp. also has aminocyclopropane-1-carboxylic acid deaminase activity and increased the growth of the brown mustard (*Brassica juncea* (L.) Czern.) plants. NBRI K28 *Enterobacter* sp. enhanced phytoextraction of metals of Ni, Zn, and Cr accumulated by *B. juncea* [178,179]. *P. putida* strain PS9, isolated from the turnip (*Brassica campestris* L.), solubilized phosphate and produced significant amount of salicylic acid, 2,3-dihydroxy benzoic acid, and indole acetic acid [180]. Antioxidant, antibacterial, and anticancer properties are present in *Brassica* spp.

A considerable number of bacterial strains have been isolated from heavy metal-polluted soil in Nanjing, China, which promoted plant growth and cadmium uptake in rape [*Brassica napus* L.] [181]. Some of these bacterial isolates had the potential to solubilize cadmium carbonate in solution culture. It has been also confirmed that these cadmium-resistant isolates exhibit the presence of indole acetic acid. These bacterial isolates colonized and developed in *B. napus* after root inoculation [181]. *P. fluorescens* G10 and *Microbacterium* sp. G16 were isolated and identified by means of 16S rDNA gene sequence analysis from the roots of *B. napus* grown in Pb-contaminated soils. There was significant increase in root elongation of inoculated *B. napus* seedlings. Endophytic bacterium JN6 isolated from roots of the drooping knotweed (*Polygonum pubescens* Blume) was identified as *Rahnella* sp. This showed very high Cd, Pb, and Zn tolerance and effectively solubilized CdCO₃, PbCO₃, and Zn₃(PO₄)₂ in culture solution [10]. *Microbacterium* sp. G16 produced indole acetic acid, siderophores, and 1-amino cyclopropane-1-carboxylate deaminase [181]. It has been demonstrated that *P. pubescens* works well as a traditional Chinese medicine. The

Proteobacteria, *Actinobacteria*, and *Bacteroidetes* Chloropid isolated from the goat willow (*Salix caprea* L.) were resistant to Zn/Cd as they produced aminocyclopropane-1-carboxylic acid deaminase, indole acetic acid, and siderophores [182]. The leaves *S. caprea* are made into a decoction which is used to cure fevers. The isolated *Bradyrhizobium* sp. (vigna) RM8 from nodules of *V. radiata* sampled from nickel and zinc in India promoted the growth of the host plant [183]. This was evidently shown by the increase in nodule numbers, leghaemoglobin, seed yield, grain protein, root N, and shoots.

Using HPLC analysis, *Enterobacter* sp. was isolated from the long-stamen onion (*Alilium macrostemon* Bunge) plants grown in polycyclic aromatic hydrocarbon-contaminated soils [184]. This bacterial species also promoted the growth of wheat and maize and removed pyrene from pyrene-amended soil in pot experiments. *Enterobacter* sp. produced indole acetic acid, siderophore, and solubilize inorganic phosphate. *A. macrostemon* has historically been used to alleviate thoracic pain, stenocardia, heart asthma, and diarrhea. *Bacillus* sp., isolated from the roots of venboksal (*Alnus firma* Siebold and Zucc.) using 16S rRNA sequence analysis, demonstrated the capacity to produce siderophores and indole acetic acid. There was increased root elongation of inoculated *B. napus* seedlings [185]. The isolates facilitated the capability of reducing heavy metal phytotoxicity and increasing Pb accumulation in *A. firma*. *Alnus* spp. are well recognized for their traditional medical uses, which include treating conditions including cancer, hepatitis, uterine cancer, rheumatism, and dysentery, as well as causing stomachaches, diarrhea, and fever. The bacterial population associated with *T. caerulescens* subsp. *calaminare* sampled had Zn and Cd capabilities due to the increased availability of the metals in soils near the roots [186]. Based on 16S rRNA sequence analysis, *Methylobacterium* spp., *Rhodococcus* spp., and *Okibacterium* spp. were isolated from the pennycress (*Thlaspi goesingense* Halácsy) accumulated Ni in ultramafic soils. These isolates produced 1-amino cyclopropane-1-carboxylic acid deaminase and siderophore [187]. Four groups of heavy metal-resistant bacterial such as *Actinobacteria*, *Proteobacteria*, *Bacteroidetes*, and *Firmicutes* were isolated from the roots, stems, and leaves of black nightshade (*Solanum nigrum* L.) [188]. These isolates were re-inoculated into *S. nigrum* under Cd stress which resulted in Cd phytotoxicity decrease. *S. nigrum* has historically been used to treat bacterial infections, coughs, and indigestion. An endophytic bacteria *Serratia* sp. RSC-14 isolated from the roots of *S. nigrum* displayed phosphate solubilization and produced indole acetic acid [189].

Endophytic bacteria associated with the roots, stems, and leaves of *Alyssum bertolonii* Desv. sampled from central Italy influenced plant growth [190]. These endophytic bacteria also shown potential for nickel-hyperaccumulation There was significant increase in biomass and metal accumulation. *Cupriavidus taiwanensis* TJ208 isolated from the bashful (*Mimosa pudica* L.) removed Pb, Cu, and Cd from polluted soils [191]. Since ancient times, *M. pudica* has been administered topically to heal wounds as well as urogenital disorders, piles, dysentery, and sinuses. *Bacillus thuringiensis* GDB-1 enhanced growth of *A. firma*, through production of aminocyclopropane-1-carboxylic acid deaminase activity, indole acetic acid, and siderophores; as well as P solubilization. *B. thuringiensis* GDB-1 also accumulated As, Cu, Pb, Ni, and Zn in seedlings of *A. firma* [192]. Zn-tolerant bacterial strains such as *B. subtilis*, *B. cereus*, *Flavobacterium* sp., and *P. aeruginosa*, isolated from the Chinese violet cress (*Orychophragmus violaceus* (L.)), significantly increased the shoot biomass and Zn accumulation in *O. violaceus* [3]. On the other hand, *B. subtilis*, *B. cereus*, *B. megaterium*, and *P. aeruginosa* isolated from *O. violaceus* significantly enhanced growth plant and Cd accumulation [193]. *O. violaceus* oil can be used to make a variety of cosmetic products for the care of the skin, hair, and lips, as well as to make external preparations for the treatment of burns. The diversity of endophytic bacteria associated with the root, stem, and leaf of *Populus* sp. enhanced phytoremediation on localities contaminated with BTEX compounds [194].

From *S. nigrum* grown in metal-polluted soil, *Acinetobacter* sp. LSE06, *Enterobacter aerogenes* LRE17, *Enterobacter* sp. LSE04, and *Serratia nematodiphila* LRE07 isolates possesses aminocyclopropane-1-carboxylic acid deaminase, indole acetic acid, siderophores, and P

solubilizing activity. *Acinetobacter* sp., *E. aerogenes*, *Enterobacter* sp., and *S. nematodiphila* significantly increased Cd extraction from the soils [195]. From a pot experiment *Pseudomonas* sp. Lk9 isolated from *S. nigrum* produces biosurfactants, siderophores, and organic acids [196]. *Serratia* sp. isolated from *S. nigrum* was resistant to the toxic effects of heavy metals through the production of indole acetic acid, siderophore, and solubilized mineral phosphate [197]. Species of *Microbacterium*, *Arthrobacter*, *Agreia*, *Bacillus*, *Sthenotrophomonas*, *Kocuria*, and *Variovorax* isolated from the roots of *Noccaea caerulea* displayed significant increases in shoot biomass, root length, and root-to-shoot Ni translocation [198]. *B. pumilus* E2S2 isolated from the stonecrop (*Sedum plumbizincicola* X.H.Guo and S.B.Zhou ex L.H.Wu) improved its phytoextraction capacity [199]. Common stonecrop is used by people for a variety of things, including coughing, high blood pressure, and wound healing. Endophytic bacterial species isolated from the Chinese brake (*Pteris vitata* L.) and the spider brake (*Pteris multifida* Poir.) improved arsenic tolerance and speciation in plants [200]. *Pteris* spp.'s bioactive potential includes some cytotoxic, anticancer, antiproliferative, neuroprotective, wound-healing, antibacterial, antiviral, hepatoprotective, leishmanicidal, trypanocidal, antinociceptive, anti-inflammatory, immunomodulatory, and chemopreventive properties.

Root-colonizing beneficial bacteria can improve plant growth through resistance to biotic and abiotic stresses. Drought is an environmental condition affecting the productivity of medicinal plants globally. PGP rhizobacteria produce secondary metabolites that could relieve drought stress in plants [201]. *Pseudomonas pseudoalcaligenes* and *B. pumilus* have a significant ability to withstand adverse effects caused by saline stress [202].

In vitro inoculation of grapevine (*Vitis vinifera* L.) explants with *Burkholderia phytofirmans* increased grapevine growth and physiological activity at a low temperature [203]. Root zone bacterial species such as *Arthrobacter*, *Azotobacter*, *Azospirillum*, *Bacillus*, *Enterobacter*, *Pseudomonas*, *Serratia*, and *Streptomyces* produce compounds that benefit living plants through abiotic stress relief [204]. *Streptomyces coelicolor*, *S. geysiriensis*, and *S. olivaceus* are drought tolerant plants grown in arid and drought-affected regions [205]. It has been established that proanthocyanidin-rich *V. vinifera* seed extract protects against a wide range of illnesses, including infections, cancer, diabetes, hypertension, peptic ulcers, and cardiovascular disease. These endophytic actinobacteria produce phytohormones, contain PGP traits, and have the water-stress tolerance potential to promote growth plants grown in stressed environments. *P. fluorescens* and *B. subtilis* isolated from *V. radiata* produce water-stress-related proteins and enzymes [206]. *B. saurashtrense* and *Pseudomonas* sp. isolated from *Salicornia brachiata* significantly increased the host's growth under salt stress conditions [55]. *Methylobacterium* sp. (strain BJ001) isolated from *Populus deltoides* × *nigra* DN34 degraded 2,4,6-trinitrotoluene (TNT), hexahydro-1,3,5-trinitro-1,3,5-triazene (RDX), and octahydro-1,3,5,7-tetranitro-1,3,5-tetrazocine (HMX) [56,158]. Rheumatism, arthritis, lower back pains, urinary complaints, digestive and liver problems, debility, anorexia, fevers, and menstrual cramp discomfort are all traditionally treated with *Populus* spp. [207]. *Bacillus*, *Pseudomonas*, *Klebsiella*, *Serratia*, *Arthrobacter*, *Streptomyces*, *Isophtericola*, and *Microbacterium* species isolated from the leaves, stems and roots of sea lavender (*Limonium sinense* (Girard) Kuntze) produced Aminocyclopropane-1-carboxylic acid deaminase and indole acetic acid. They are also capable of N₂-fixation and phosphate-solubilization [57]. *Limonium* species have antibacterial, antioxidant, free radical-scavenging, and antiviral properties.

A. linearis and *Cyclopia* spp. are South African indigenous herbal leguminous species grown in acidic soils. Among the rhizobial isolates from root nodules of *A. 24spalathus* and *Cyclopia* spp., bacterial species of genera *Rhizobium*, *Burkholderia*, *Mesorhizobium*, and *Bradyrhizobium* produce bioactive compounds that affect the growth of leguminous plants [58].

A heavy-metal-resistant strain of *Bacillus edaphicus* NBT was evaluated on *B. juncea* for its plant growth promotion. *B. edaphicus* NBT produced indole acetic acid, siderophores, and aminocyclopropane-1-carboxylic acid deaminase. There was also an increase in Pb uptake by *B. juncea* inoculated with *B. edaphicus* NBT [208]. In pot experiments, 16S rDNA sequencing identified *E. aerogenes* and *R. aquatilis* isolated from *B. juncea*. These isolates

stimulated the growth of *B. juncea* exposed to environments contaminated with Ni and Cr [209]. These bacteria also produced siderophores, aminocyclopropane-1-carboxylic acid deaminase, indole acetic acid, and phosphate solubilization [209]. *B. pumilus* (STR2) and *Exiguobacterium oxidotolerans* (STR36) promoted the growth of the water hyssop (*Bacopa monnieri* (L.) Pennell) grown in salt-stressed soils, enhanced proline levels and decreased lipid peroxidation [76]. Traditional medicine from *B. monnieri* may improve cognitive performance, cure ADHD symptoms, and lessen stress and anxiety.

The jute mallow or nalta jute (*Corchorus olitorius* L.) inoculated with *P. extremorientalis* TSAU6, indole acetic acid, and gibberellic acid exhibited a significant increase in root length, shoot length, and fresh weight, indicating that plant growth regulators such as auxins and gibberellins play an important role in plant salinity tolerance [59]. *C. olitorius* is a leafy vegetable that is frequently used in soup recipes and traditional medicine to treat tumors, chronic cystitis, and fever. *B. megaterium* MTCC446 isolated from gale of the wind (*Phyllanthus amarus* Schumach. and Thonn.) promoted a higher vigor index, germination (%), plant biomass, P content, plant phenolic content, radical scavenging, and antioxidant activity [60]. *P. amarus* is frequently used in African traditional medicine to treat a variety of illnesses, including kidney stones, dysentery, jaundice, diarrhea, and urogenital problems.

Under the pot experiment, *Achromobacter xylosoxidans* isolated from the bright eyes (*Catharanthus roseus* (L.) G. Don) exposed to saline soils in Tamilnadu, India, produced aminocyclopropane-1-carboxylic acid deaminase [210]. *C. roseus* is a significant medicinal plant that is found around the world. It contains a variety of phytochemicals that have biological effects (antioxidant, antibacterial, antifungal, and anticancer). Under drought conditions, the ringed lavender (*Lavandula dentata* L.) isolates of *B. thuringiensis* increased plant growth and nutrition. *B. thuringiensis* produced indole acetic acid and aminocyclopropane-1-carboxylic acid deaminase and solubilized P, demonstrating its capacity to enhance plant growth under stress conditions [102]. In traditional medicine, *L. dentata* has been used to cure rheumatism, headaches, colds, and the flu.

Environmental contamination became a major challenge in recent decades due to rapid industrialization in developed countries. Mining activities, wastewater discharge, volcanic eruptions, and rock weathering affected the growth and productivity of soil. Endophytic bacterial species could be a potential mechanism in phytoremediation strategies for the management of environmental contaminants, while plants benefit through growth promotion (Table 3).

Table 3. Phytoremediation bacteria and associated secondary metabolites from medicinal and herbal plant species.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Isolated Plant Part/Region	References
<i>Pseudomonas aeruginosa</i> , <i>Pseudomonas savastanoi</i>	Mono- and dechlorinated, benzoic acids production	<i>Elymus dauricus</i>		[211]
<i>Methylobacterium populi</i>	Methane; 2,4,6-trinitrotoluene; hexahydro-1,3,5-trinitro-1,3,5-triazene; octahydro-1,3,5,7-tetranitro-1,3,5-tetrazocine; benzene, toluene, ethylbenzene, xylene production	<i>Populus deltoids x nigra</i>	NM	[212]
<i>Pseudomonas</i> sp., <i>Bacillus cepacia</i>	Benzene, toluene, ethylbenzene, xylene production	<i>Populus</i> sp.	NM	[213]
<i>Burkholderia cepacia</i>	Volatile organic compounds, toluene production	<i>Lupinus luteus</i>	NM	[214]

Table 3. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Isolated Plant Part/Region	References
<i>Pseudomonas putida</i>	2,4-Dichlorophenoxyacetic acid production	<i>Populus</i> sp., <i>Trichocarpa deltoidea</i> cv. Hoogvorst	Stem	[213]
<i>Proteobacteria</i> sp.	NM	<i>Populus nigra</i> cv. <i>Brandaris</i>	Root, shoot	[215]
<i>Proteobacteria</i> sp.	NM	<i>Lolium multiflorum</i> cv. <i>Lolita</i>	Root, shoot	[215]
<i>Proteobacteria</i> sp.	NM	<i>Medicago sativa</i> cv. <i>Europ</i>	Root, shoot	[215]
<i>Pseudomonas</i> ! <i>uorescens</i> G10, <i>Microbacterium</i> sp. G16 (EN)	indole acetic acid, siderophores, and 1-aminocyclopropane-1-carboxylate deaminase production	<i>Brassica napus</i>	Root	[216]
<i>Arthrobacter</i> sp. MT16, <i>Microbacterium</i> sp. JYC17, <i>Pseudomonas chlororaphis</i> SZY6	NM	<i>Brassica napus</i>	Whole plant	[217]
<i>Firmicutes</i> sp., <i>Actinobacteria</i> sp., <i>Proteobacteria</i> sp. (EN)	NM	<i>Elsholtzia splendens</i> , <i>Commelina communis</i>	Whole plant	[218]
<i>Enterobacter</i> sp.	NM	<i>Allium macrostemon</i>	Stem	[219]
<i>Sphingopyxis</i> sp., <i>Pseudomonas</i> sp.	NM	<i>Lolium multiflorum</i> , <i>Lotus corniculatus</i>	Root, shoot	[220]
<i>Achromobacter xylosoxidans</i>	NM	<i>Phragmites australis</i> , <i>Ipomoea aquatica</i> , <i>Vetiveria zizanioides</i>	Root	[221]
<i>Burkholderia macroides</i>	NM	<i>Populus</i> cv. Hoogvorst	Stem	[222]
<i>Pseudomonas putida</i>	NM	<i>Populus trichocarpa</i> × <i>deltoidea</i> cv. Hoogvorst	Stem	[222]
<i>Pseudomonas tolaasii</i> , <i>P. jessenii</i> , <i>Ps. Rhodesiae</i> , <i>P. plecoglossicida</i> , <i>P. veronii</i> , <i>P. fulva</i> , <i>P. oryzihabitans</i> , <i>Acinetobacter lwoffii</i> , <i>A. nicotianae</i> , <i>Bacillus megaterium</i> , <i>Paenibacillus amylolyticus</i>	NM	<i>Populus</i> sp. cv. <i>Hazendans</i>	Root, stem	[15]
<i>Pseudomonas putida</i>	NM	<i>Populus</i> sp.	NM	[223]
<i>Staphylococcus</i> sp., <i>Microbacterium</i> sp., <i>Pseudomonas</i> sp., <i>Staphylococcus</i> sp., <i>Curtobacterium</i> sp., <i>Microbacterium</i> sp., <i>Curtobacterium</i> sp., <i>Staphylococcus</i> sp., <i>Bacillus</i> sp., <i>Arthrobacter</i> sp., <i>Pseudomonas</i> sp., <i>Curtobacterium</i> sp., <i>Microbacterium</i> sp., <i>Paenibacillus</i> sp., <i>Leifsonia</i> sp.	NM	<i>Alyssum bertolonii</i>	Leaf, stem, root	[224]
<i>Bacillus</i> sp.	NM	<i>Alnus firma</i>	Root	[225]

Table 3. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Isolated Plant Part/Region	References
<i>Sphingomonas</i> sp., <i>Methylobacterium</i> sp., <i>Sphingobacterium multivorum</i> , <i>Phyllobacterium</i> sp., <i>Devosia</i> sp., <i>Afibia</i> sp., <i>Sphingomonas</i> sp., <i>Rhodococcus</i> sp.	NM	<i>Thlaspi caerulescens</i>	Stem, root	[226]
<i>Alphaproteobacteria</i> sp., <i>Holophaga</i> sp., <i>Acidobacterium</i> sp., <i>Betaproteobacteria</i> sp., <i>Gammaproteobacteria</i> sp., <i>Bacillus</i> sp., <i>Blastococcus</i> sp., <i>Propionibacterium acnes</i> , <i>Flavobacterium</i> sp., <i>Desulfitobacterium</i> <i>metallireductans</i> , <i>M. mesophilicum</i> , <i>M. extorquens</i> , <i>Sphingomonas</i> sp., <i>Curtobacterium</i> sp., <i>Plantibacter flavus</i> , <i>Rhodococcus</i> sp.	NM	<i>Thlaspi goesingense</i>	Stem	[227]
<i>Microbacterium</i> sp., <i>Bacillus</i> sp., <i>Arthrobacter</i> sp., <i>Flavobacterium</i> sp., <i>Chryseobacterium</i> sp., <i>Agrobacterium</i> sp., <i>Sphingomonas</i> sp., <i>Pseudomonas</i> sp., <i>Serratia</i> sp., <i>Curtobacteriu</i> sp.	NM	<i>Solanum nigrum</i>	Root, stem, leaf	[228]
<i>Acinetobacter</i> sp., <i>Bacillus</i> sp.	Aminocyclopropane-1-carboxylic acid deaminase production	<i>Commelina communis</i>	Root, stem, leaf	[229]
<i>Acinetobacter</i> sp., <i>Moraxella</i> sp., <i>Serratias</i> sp., <i>Herbaspirillum</i> sp., <i>Bukholderia</i> sp., <i>Paracoccus</i> sp., <i>Sphingomonas</i> sp., <i>Exiguobacterium</i> sp., <i>Bacillus</i> sp., <i>Arthrobacter</i> sp., <i>Microbacterium</i> sp., <i>Micrococcus</i> sp.	NM	<i>Elsholtzia splendens</i> and <i>Commelina communis</i>	Root, stem, leaf	[230]
<i>Enterobacter</i> sp.	NM	<i>Allium macrostemon</i>	Stem	[231]
<i>Microbacterium</i> sp., <i>Frigoribacterium</i> sp., <i>Methylobacterium</i> sp., <i>Sphingomonas</i> sp.	NM	<i>Salix caprea</i>	Stem, leaf	[232]
<i>Pseudomonas frederiksbergensis</i> sp. <i>Veronii</i> , <i>P. Putida</i> , <i>Arthrobacter illicis</i> , <i>A. histidinolovorans</i>	NM	<i>Populus</i> sp. cv. <i>Hazendans</i> and <i>Populus</i> sp. cv. <i>Hoogvorst</i>	Root, stem	[168]
<i>Staphylococcus</i> sp., <i>Microbacterium</i> sp., <i>Pseudomonas</i> sp., <i>Curtobacterium</i> sp., <i>Bacillus</i> sp., <i>Arthrobacter</i> sp., <i>Paenibacillus</i> sp., <i>Leifsonia</i> sp.	NM	<i>A. bertolonii</i>	Whole plant	[168]
<i>Pseudomonas</i> sp., <i>Streptomyces</i> sp.	NM	<i>A. bertolonii</i>	Rhizosphere	[168]

Table 3. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Isolated Plant Part/Region	References
<i>Holophaga</i> sp., <i>Acidobacterium</i> sp., <i>Gammaproteobacteria</i> sp., <i>Betaproteobacteria</i> sp., <i>Alphaproteobacteria</i> sp., <i>Verrucomicrobia</i> sp., <i>Gemmatimonadetes</i> sp.	NM	<i>Thlaspi goesingense</i>	Rhizosphere, shoot	[168]
<i>Pseudomonas fluorescens</i> G10, <i>Microbacterium</i> sp. G16	Indole acetic acid, aminocyclopropane-1- carboxylic acid deaminase, siderophore production	<i>Brassica napus</i>	Root, shoot	[172]
<i>Enterobacter cloacae</i> CAL2	Indole acetic acid, aminocyclopropane-1- carboxylic acid deaminase, siderophores, antibiotics production	<i>B. napus</i>	Root, shoot	[172]
<i>Cupriavidus taiwanensis</i>	Biodegradation, biosorption, release of extracellular products	<i>Mimosa pudica</i>	Root, shoot	[172]
<i>Bacillus thuringiensis</i> GDB-1	Aminocyclopropane-1- carboxylic acid deaminase, indole acetic acid, Siderophores	<i>Alnus firma</i>	Root, shoot	[172]
<i>B. pumilus</i> E2S2, <i>Bacillus</i> sp. E1S2	Indole acetic acid, aminocyclo-pro-pane-1- carboxylic acid deaminase, siderophores	<i>Sedum plumbizincicola</i>	Root, shoot	[172]
<i>Pseudomonas tolaasii</i> ACC23, <i>P. fluorescens</i> ACC9	Aminocyclo-pro-pane-1- carboxylic acid deaminase, siderophores, and indole acetic acid production	<i>B. napus</i>	Root, shoot	[172]
<i>Pseudomonas</i> sp. LK9	Biosurfactants, siderophores, organic acids production	<i>Solanum nigrum</i>	Root, stem, leaf	[172]
<i>Pseudomonas</i> sp. PsM6, <i>P. Jensenii</i> PjM15	Biosorption, mobilization, aminocyclopropane-1- carboxylic acid deaminase, indole acetic acid, siderophores production	<i>Ricinus communis</i>	Root, stem, leaf	[172]
<i>Rahnella</i> sp. JN6	Indole acetic acid, aminocyclopropane-1- carboxylic acid deaminase, siderophores	<i>B. napus</i>	Root, shoot	[172]
<i>Bacillus subtilis</i> , <i>B. cereus</i> , <i>Flavobacterium</i> sp., <i>Pseudomonas aeruginosa</i>	Aminocyclopropane-1- carboxylic acid deaminase, indole acetic acid, siderophores	<i>Orycophragmus violaceus</i>	Root, shoot	[172]
<i>Pseudomonas veronii</i>	indole acetic acid production, decrease soil pH, supply P, and Fe	<i>S. alfredii</i>	Root, shoot	[172]

Table 3. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Isolated Plant Part/Region	References
<i>Staphylococcus arlettae</i> NBRIEAG-6	indole acetic acid, siderophores, Aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica juncea</i>	Root, shoot	[172]
<i>Achromobacter xylosoxidans</i> Ax10	Aminocyclopropane-1-carboxylic acid deaminase, indole acetic acid production	<i>B. Juncea</i>	Root, shoot	[172]
<i>Psychrobacter</i> sp. SRA1, <i>Bacillus cereus</i> SRA10	Aminocyclopropane-1-carboxylic acid deaminase, indole acetic acid, Ni mobilization	<i>B. Juncea</i>	Root, shoot	[172]
<i>Pseudomonas</i> sp. SRI2, <i>Psychrobacter</i> sp. SRS8, <i>Bacillus</i> sp. SN9	Aminocyclopropane-1-carboxylic acid deaminase, indole acetic acid production; Ni mobilization	<i>B. Juncea</i>	Root, shoot	[172]
<i>Pseudomonas</i> sp. SRI2, <i>Psychrobacter</i> sp. SRS8, <i>Bacillus</i> sp. SN9	Aminocyclopropane-1-carboxylic acid deaminase, indole acetic acid production; Ni mobilization	<i>Brassica oxyrrhina</i>	Root, shoot	[172]
<i>Paenibacillus macerans</i> NBRFT5, <i>Bacillus endophyticus</i> NBRFT4, <i>B. pumilus</i> NBRFT9	Siderophores, organic acids, protons, and other non-specified enzymes production	<i>B. Juncea</i>	Root, stem, leaf	[172]
<i>Rhizobium leguminosarum</i>	Metal chelation	<i>B. Juncea</i>	Whole plant	[172]
<i>Azotobacter chroococcum</i> HKN-5, <i>Bacillus megaterium</i> HKP-1, <i>Bacillus mucilaginosus</i> HKK-1	indole acetic acid, gibberellins production	<i>B. Juncea</i>	Shoot	[172]
<i>Pantoea agglomerans</i> Jp3-3, <i>Pseudomonas thivervalensis</i> Y1-3-9	Indole acetic acid, siderophores, Aminocyclopropane-1-carboxylic acid deaminase production	<i>B. napus</i>	Root, shoot	[172]
<i>Enterobacter</i> sp. JYX7, <i>Klebsiella</i> sp. JYX10	Indole acetic acid, siderophores, Aminocyclopropane-1-carboxylic acid deaminase production	<i>Polygonum pubescens</i>	Root, shoot	[172]
<i>Rahnella</i> sp.	Indole acetic acid, siderophores, aminocyclopropane-1-carboxylic acid deaminase production	<i>Amaranthus hypochondriacus</i> , <i>A. mangostanus</i> , <i>Solanum nigrum</i>	Root, shoot	[172]
<i>Kluyvera</i> sp.	Aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica napus</i>	NM	[172]
<i>Kluyver</i> spp.	Aminocyclopropane-1-carboxylic acid deaminase, siderophores production	<i>Brassica juncea</i>	NM	[172]
<i>Brevibacillus</i> sp.	Decreased lead uptake; indole acetic acid production	<i>Trifolium pratense</i>	NM	[172]

Table 3. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Isolated Plant Part/Region	References
<i>Enterobacter cloacae</i> CAL2	Aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica napus</i>	NM	[172]
<i>Microbacterium arabinogalactanolyticum</i>	Increased nickel uptake	<i>Alyssum murale</i>	NM	[172]
<i>Psuedomonas</i> sp.	Increased biomass; indole acetic acid production	<i>Brassica napus</i>	NM	[172]
<i>Variovorax paradoxus</i> , <i>Rhodococcus</i> sp., <i>Flavobacterium</i> sp.	Increased root length; Indole acetic acid, siderophores, production Aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica juncea</i>	NM	[172]
<i>Pseudomonas fluorescens</i> , <i>P. putida</i>	Increased seed germination and growth	<i>Brassica napus</i>	NM	[172]
<i>P. putida</i> UW4, <i>P. putida</i> HS-2	Increased biomass in the field; indole acetic acid, Aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica napus</i>	NM	[172]
<i>Sinorhizobium</i> sp. Pb002	Increased plant survival and lead uptake; aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica juncea</i>	NM	[172]
<i>Azotobacter chroococcum</i> HKN-5, <i>B. megaterium</i> HKP-1, <i>B. mucilaginosus</i> HKK-1	Increased biomass and metal bioavailability	<i>Brassica juncea</i>	NM	[172]
<i>B. subtilis</i> SJ-101	Increased nickel uptake; indole acetic acid production	<i>Brassica juncea</i>	NM	[172]
<i>Pseudomonas</i> sp. RJ10, <i>Bacillus</i> sp. RJ16	Increased biomass and metal uptake; indole acetic acid production	<i>Brassica napus</i>	NM	[172]
<i>Mesorhizobium huakuii</i> subsp. <i>Rengei</i> B3	Increased metal accumulation: bacterium expresses phytochelatin, and metallothionein	<i>Astragalus sinicus</i>	NM	[172]
<i>Burkholderia cepacia</i>	Increased biomass, metal uptake, and translocation of metal to shoots	<i>Sedum alfredii</i>	NM	[172]
<i>P. putida</i> ARB86	Increased biomass and chlorophyll content	<i>Arabidopsis thaliana</i>	NM	[172]
<i>Enterobacter</i> sp. NBRI K28	Increased metal uptake; indole acetic acid, siderophores, Aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica juncea</i>	NM	[172]

Table 3. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Isolated Plant Part/Region	References
<i>P. putida</i> HS-2	Increased seed germination and biomass; siderophores, indole acetic acid, Aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica napus</i>	NM	[172]
<i>Bacillus</i> sp. J119	Increased cadmium uptake, indole acetic acid, siderophores production; biosurfactant production	<i>Brassica napus</i>	NM	[172]
<i>P. aeruginosa</i> MKRh3	Decreased cadmium uptake; indole acetic acid, siderophores, Aminocyclopropane-1-carboxylic acid deaminase production	<i>Vigna mungo</i>	NM	[172]
<i>Pseudomonas</i> sp. 29C, <i>Bacillus</i> sp. 4C	Increased biomass; indole acetic acid, siderophores, aminocyclopropane-1-carboxylic acid deaminase production;	<i>Brassica juncea</i>	NM	[172]
<i>Pseudomonas</i> sp. M6, <i>Pseudomonas jessenii</i> M15	Increased biomass; indole acetic acid, Aminocyclopropane-1-carboxylic acid deaminase production	<i>Ricinus communis</i>	NM	[172]
<i>Proteus vulgaris</i> KNP3	Increased germination, biomass, and chlorophyll, and decreased metal uptake	<i>Cajanus cajan</i>	NM	[172]
<i>Pseudomonas</i> sp.	Increased biomass and decreased metal uptake; siderophores production	<i>Cicer arietinum</i>	NM	[172]
<i>P. fluorescens</i> G10, <i>Microbacterium</i> sp. G16	Increased biomass and metal uptake; indole acetic acid, siderophores, aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica napus</i>	NM	[172]
<i>Bacillus edaphicus</i> NBT	Increased biomass; indole acetic acid, siderophores, aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica juncea</i>	NM	[172]
<i>Flavobacterium</i> sp.	Increased root length, biomass, metal uptake	<i>Orychophragmus violaceus</i>	NM	[172]
<i>Achromobacter xylosoxidans</i> Ax10	Increased root and shoot length and biomass; aminocyclopropane-1-carboxylic acid deaminase production; indole acetic acid production	<i>Brassica juncea</i>	NM	[172]

Table 3. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Isolated Plant Part/Region	References
<i>Enterobacter aerogenes</i> , <i>Rahnella aquatilis</i>	Increased biomass and metal uptake; indole acetic acid, siderophores, aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica juncea</i>	NM	[172]
<i>Kluyvera</i> sp.	Increased biomass; aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica napus</i>	NM	[172]
<i>Kluyvera</i> sp.	Increased biomass; aminocyclopropane-1-carboxylic acid deaminase, siderophores production	<i>Brassica napus</i>	NM	[172]
<i>Microbacterium arabinogalactanolyticum</i>	Increased Ni uptake	<i>Alyssum murale</i>	NM	[172]
<i>P. fluorescens</i> , <i>P. putida</i>	Increased seed germination and growth	<i>Brassica napus</i>	NM	[172]
<i>P. putida</i> UW4, <i>P. putida</i> HS-2	Indole acetic acid, aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica napus</i>	NM	[172]
<i>B. subtilis</i> SJ-101	Increased Ni, indole acetic acid production	<i>Brassica juncea</i>	NM	[172]
<i>Bradyrhizobium</i> sp. RM8	Decreased Ni toxicity and uptake; indole acetic acid, siderophores, hydrogen cyanide, ammonia production	<i>Vigna mungo</i>	NM	[172]
<i>Rhizobium</i> sp. RP5	Decreased Ni, Zn uptake, and toxicity; indole acetic acid, siderophores production	<i>Pisum sativum</i>	NM	[172]
<i>Enterobacter</i> sp. NBRI K28	Increased Ni, Zn, Cr uptake; I indole acetic acid, siderophores, Aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica juncea</i>	NM	[172]
<i>P. putida</i> HS-2	Siderophores, indole acetic acid, Aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica napus</i>	NM	[172]
<i>Pseudomonas</i> sp. 29C, <i>Bacillus</i> sp. 4C	indole acetic acid, siderophores production, Aminocyclopropane-1-carboxylic acid deaminase	<i>Brassica juncea</i>	NM	[172]
<i>Pseudomonas</i> sp. M6, <i>Pseudomonas jessenii</i> M15	indole acetic acid, aminocyclopropane-1-carboxylic acid deaminase production	<i>Ricinus communis</i>	NM	[172]

Table 3. Cont.

Isolated Bacterial Species	Biochemical/Physiological Activity	Host Medicinal Plant Species	Isolated Plant Part/Region	References
<i>Pseudomonas</i> sp.	Decreased Ni uptake; siderophores production	<i>Cicer arietinum</i>	NM	[172]
<i>Enterobacter erogenes</i> , <i>Rahnella aquatilis</i>	Increased Ni, Cr uptake; indole acetic acid, siderophores, aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica juncea</i>	NM	[172]
<i>Psychrobacter</i> sp. SRA1 and SRA2, <i>Bacillus cereus</i> SRA10	Increased Ni bioavailability and uptake; indole acetic acid, siderophores, aminocyclopropane-1-carboxylic acid deaminase production	<i>Brassica juncea</i> , <i>B. oxyrrhina</i>	NM	[172]
<i>Brachybacterium</i>	Production of halotolerant properties	<i>Salicornia brachiata</i> r	Rhizosphere	[233]
<i>Pseudomonas</i> sp. SRI2, <i>Psychrobacter</i> sp. SRS8 and <i>Bacillus</i> sp. SN9	NM	<i>Brassica juncea</i> , <i>B. oxyrrhina</i>	NM	[172]

NM = not mentioned.

3. Conclusions

The sustainable production of medicinal and herbal plants has been one of the major challenges facing agriculture in recent years, with the ongoing over-utilization of chemicals to meet the population demands. To solve these problems, an environmentally friendly way forward focusing on the minimal usage of agrochemicals is required. Endophytic bacterial isolates could be a potential source of phytochemical compounds to enhance plant production. In addition, endophytic bacteria enable the plant species to resist abiotic stress conditions. Endophytic bacterial living in plant tissues produce plant growth-promoting compounds such as phytohormones; enzymes such as Aminocyclopropane-1-carboxylic acid deaminase, which reduce the levels of ethylene; organic acids aiding in P solubilization; and siderophores, cellulases, and chitinases inhibiting the phytopathogens growth. Sustainable agriculture provides a platform to medicinal and herbal plant producers from which to apply new agricultural techniques and biotechnologies to enhance plant growth by using bacterial isolates as biofertilizers. The modes of actions of several endophytic bacterial species have been well documented; they are recognised as plant growth promotion agents based on other biochemical and physiological attributes such as biological nitrogen fixation, phosphate solubilization, siderophore production, and the synthesis of PGP substances. In addition to improving plant nutrient availability and providing protection against varied abiotic and biotic stresses, endophytic bacteria play a pivotal role in enhancing medicinal and herbal plant productivity while simultaneously ensuring the sustainable maintenance of soil health.

Author Contributions: All authors (P.P.T., K.N. and F.N.M.) contributed equally to this work. K.N. and F.N.M. critically reviewed the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data is unavailable.

Conflicts of Interest: The authors declare no conflict of interest.

References

- Melotto, M.; Underwood, W.; He, S.Y. Role of stomata in plant innate immunity and foliar bacterial diseases. *Annu. Rev. Phytopathol.* **2008**, *46*, 101–122. [\[CrossRef\]](#)
- Çakmakçı, R.; Mosber, G.; Milton, A.H.; Alatürk, F.; Ali, B. The effect of auxin and auxin-producing bacteria on the growth, essential oil yield, and composition in medicinal and aromatic plants. *Curr. Microbiol.* **2020**, *77*, 564–577.
- Suman, A.; Yadav, A.N.; Verma, P. Endophytic microbes in crops: Diversity and beneficial impact for sustainable agriculture. In *Microbial Inoculants in Sustainable Agricultural Productivity*; Springer: New Delhi, India, 2016; pp. 117–143.
- De Melo Pereira, G.V.; Magalhães, K.T.; Lorenzetti, E.R.; Souza, T.P.; Schwan, R.F. A multiphasic approach for the identification of endophytic bacterial in strawberry fruit and their potential for plant growth promotion. *Microb. Ecol.* **2012**, *63*, 405–417. [\[CrossRef\]](#)
- Fira, D.; Dimkić, I.; Berić, T.; Lozo, J.; Stanković, S. Biological control of plant pathogens by *Bacillus* species. *J. Biotechnol.* **2018**, *285*, 44–55. [\[CrossRef\]](#) [\[PubMed\]](#)
- Duhan, P.; Bansal, P.; Rani, S. Isolation, identification, and characterization of endophytic bacteria from medicinal plant *Tinospora cordifolia*. *S. Afr. J. Bot.* **2020**, *134*, 43–49. [\[CrossRef\]](#)
- Franch, C.; Lindström, K.; Elmerich, C. Nitrogen-fixing bacteria associated with leguminous and non-leguminous plants. *Plant Soil* **2009**, *321*, 35–59. [\[CrossRef\]](#)
- Cocking, E.C. Endophytic colonization of plant roots by nitrogen-fixing bacteria. *Plant Soil* **2003**, *252*, 169–175. [\[CrossRef\]](#)
- Arshad, M.; Saleem, M.; Hussain, S. Perspectives of bacterial ACC deaminase in phytoremediation. *TRENDS Biotechnol.* **2007**, *25*, 356–362. [\[CrossRef\]](#) [\[PubMed\]](#)
- Eid, A.M.; Salim, S.S.; Hassan, S.E.D.; Ismail, M.A.; Fouda, A. Role of endophytes in plant health and abiotic stress management. In *Microbiome in Plant Health and Disease*; Springer: Singapore, 2019; pp. 119–144.
- Anjum, N.; Chandra, R. Endophytic bacteria: Optimization of isolation procedure from various medicinal plants and their preliminary characterization. *Asian J. Pharm. Clin. Res.* **2015**, *8*, 233–238.
- Islam, M.R.; Sultana, T.; Joe, M.M.; Yim, W.; Cho, J.C.; Sa, T. Nitrogen-fixing bacteria with multiple plant growth-promoting activities enhance growth of tomato and red pepper. *J. Basic Microbiol.* **2013**, *53*, 1004–1015. [\[CrossRef\]](#)
- Costacurta, A.; Vanderleyden, J. Synthesis of phytohormones by plant-associated bacteria. *Crit. Rev. Microbiol.* **1995**, *21*, 1–18. [\[CrossRef\]](#)
- Jiménez-Gómez, A.; García-Estévez, I.; García-Fraile, P.; Escribano-Bailón, M.T.; Rivas, R. Increase in phenolic compounds of *Coriandrum sativum* L. after the application of a *Bacillus halotolerans* biofertilizer. *J. Sci. Food Agric.* **2020**, *100*, 2742–2749. [\[CrossRef\]](#) [\[PubMed\]](#)
- Ibrahim, E.; Fouad, H.; Zhang, M.; Zhang, Y.; Qiu, W.; Yan, C.; Li, B.; Mo, J.; Chen, J. Biosynthesis of silver nanoparticles using endophytic bacteria and their role in inhibition of rice pathogenic bacteria and plant growth promotion. *RSC Adv.* **2019**, *9*, 29293–29299. [\[CrossRef\]](#) [\[PubMed\]](#)
- Nouri, J.; Khorasani, N.; Lorestani, B.; Karami, M.; Hassani, A.H.; Yousefi, N. Accumulation of heavy metals in soil and uptake by plant species with phytoremediation potential. *Environ. Earth Sci.* **2009**, *59*, 315–323. [\[CrossRef\]](#)
- Ghorbani, R.; Wilcockson, S.; Koocheki, A.; Leifert, C. Soil management for sustainable crop disease control: A review. *Org. Farming Pest Control. Remediat. Soil Pollut.* **2008**, *6*, 177–201. [\[CrossRef\]](#)
- Yu, H.; Zhang, L.; Li, L.; Zheng, C.; Guo, L.; Li, W.; Sun, P.; Qin, L. Recent developments and future prospects of antimicrobial metabolites produced by endophytes. *Microbiol. Res.* **2010**, *165*, 437–449. [\[CrossRef\]](#) [\[PubMed\]](#)
- Dimkpa, C.O.; Bindraban, P.S. Fortification of micronutrients for efficient agronomic production: A review. *Agron. Sustain. Dev.* **2016**, *36*, 1–27.
- Maghanga, J.K.; Kituyi, J.L.; Kisinyo, P.O.; Ng'Etich, W.K. Impact of nitrogen fertilizer applications on surface water nitrate levels within a Kenyan tea plantation. *J. Chem.* **2013**, *2013*, 196516. [\[CrossRef\]](#)
- Çakmakçı, R.; Dönmez, M.F.; Ertürk, Y.; Erat, M.; Haznedar, A.; Sekban, R. Diversity and metabolic potential of culturable bacteria from the rhizosphere of Turkish tea grown in acidic soils. *Plant Soil* **2010**, *332*, 299–318. [\[CrossRef\]](#)
- Sen, S.; Rai, M.; Das, D.; Chandra, S.; Acharya, K. Blister blight a threatened problem in tea industry: A review. *J. King Saud Univ. Sci.* **2020**, *32*, 3265–3272. [\[CrossRef\]](#)
- Photolo, M.M.; Mavumengwana, V.; Sitole, L.; Tlou, M.G. Antimicrobial and antioxidant properties of a bacterial endophyte, *Methylobacterium radiotolerans* MAMP 4754, isolated from combretum erythrophyllum seeds. *Int. J. Microbiol.* **2020**, *2020*, 9483670. [\[CrossRef\]](#) [\[PubMed\]](#)
- Narkhede, M.B. Investigation of in vitro α -amylase and α -glucosidase inhibitory activity of polyherbal extract. *Int. J. Pharm. Res. Dev.* **2021**, *3*, 97–103.
- Punithavathi, M.; Aranganathan, J.; Janani, M. Antibacterial activity and phytochemical screening of *Ocimum sanctum* Linn. (Leaves). *Int. J. Life Sci.* **2014**, *3*, 28–30. [\[CrossRef\]](#)
- Sankuratri, A.; Talari, A.K.; Pokala, T. A review on endophytic bacteria, and their uses. *Int. J. Eng. Sci. Comput.* **2021**, *11*, 28105–28111.

27. Mitra, S.; Naskar, N.; Chaudhuri, P. A review on potential bioactive phytochemicals for novel therapeutic applications with special emphasis on mangrove species. *Phytomed. Plus* **2021**, *1*, 100107. [\[CrossRef\]](#)
28. Ali, M.; Khan, T.; Fatima, K.; Ali, Q.U.A.; Ovais, M.; Khalil, A.T.; Ullah, I.; Raza, A.; Shinwari, Z.K.; Idrees, M. Selected hepatoprotective herbal medicines: Evidence from ethnomedicinal applications, animal models, and possible mechanism of actions. *Phytother. Res.* **2018**, *32*, 199–215. [\[CrossRef\]](#)
29. Anagha, K.; Manasi, D.; Priya, L.; Meera, M. Antimicrobial activity of yashtimadhu (*Glycyrrhiza glabra* L.)—a review. *Int. J. Curr. Microbiol. Appl. Sci.* **2014**, *3*, 329–336.
30. Messier, C.; Epifano, F.; Genovese, S.; Grenier, D. Licorice, and its potential beneficial effects in common oro-dental diseases. *Oral Dis.* **2012**, *18*, 32–39. [\[CrossRef\]](#) [\[PubMed\]](#)
31. El-Saber Batiha, G.; Magdy Beshbishy, A.; El-Mleeh, A.; Abdel-Daim, M.M.; Prasad Devkota, H. Traditional uses, bioactive chemical constituents, and pharmacological and toxicological activities of *Glycyrrhiza glabra* L. (Fabaceae). *Biomolecules* **2020**, *10*, 352. [\[CrossRef\]](#)
32. Yang, R.; Han, M.; Fu, Z.; Wang, Y.; Zhao, W.; Yu, G.; Ma, Z. Immune responses of Asian seabass *Lates calcarifer* to dietary *Glycyrrhiza uralensis*. *Animals* **2020**, *10*, 1629. [\[CrossRef\]](#)
33. Krishna, P.M.; KNV, R.; Banji, D. A review on phytochemical, ethnomedical and pharmacological studies on genus *Sophora*, Fabaceae. *Rev. Bras. Farmacogn.* **2012**, *22*, 1145–1154. [\[CrossRef\]](#)
34. Wang, R.; Deng, X.; Gao, Q.; Wu, X.; Han, L.; Gao, X.; Zhao, S.; Chen, W.; Zhou, R.; Li, Z.; et al. *Sophora alopecuroides* L.: An ethnopharmacological, phytochemical, and pharmacological review. *J. Ethnopharmacol.* **2020**, *248*, 112172. [\[CrossRef\]](#) [\[PubMed\]](#)
35. Zhao, L.; Deng, Z.; Yang, W.; Cao, Y.; Wang, E.; Wei, G. Diverse rhizobia associated with *Sophora alopecuroides* grown in different regions of Loess Plateau in China. *Syst. Appl. Microbiol.* **2010**, *33*, 468–477. [\[CrossRef\]](#)
36. Yang, W.; Xu, Q.; Liu, H.X.; Wang, Y.P.; Wang, Y.M.; Yang, H.T.; Guo, J.H. Evaluation of biological control agents against *Ralstonia* wilt on ginger. *Biol. Control.* **2012**, *62*, 144–151. [\[CrossRef\]](#)
37. Zadeh, J.B.; Kor, N.M. Physiological and pharmaceutical effects of ginger (*Zingiber officinale* Roscoe) as a valuable medicinal plant. *Eur. J. Exp. Biol.* **2014**, *4*, 87–90.
38. Shahrajabian, M.H.; Sun, W.; Cheng, Q. Clinical aspects, and health benefits of ginger (*Zingiber officinale*) in both traditional Chinese medicine and modern industry. *Acta Agric. Scand. Sect. B—Soil Plant Sci.* **2019**, *69*, 546–556. [\[CrossRef\]](#)
39. Lötter, D.; le Maitre, D. Modelling the distribution of *Aspalathus linearis* (Rooibos tea): Implications of climate change for livelihoods dependent on both cultivation and harvesting from the wild. *Ecol. Evol.* **2014**, *4*, 1209–1221. [\[CrossRef\]](#)
40. Hassen, A.I.; Bopape, F.L.; Habig, J.; Lamprecht, S.C. Nodulation of rooibos (*Aspalathus linearis* Burm. f.), an indigenous South African legume, by members of both the α -Proteobacteria and β -Proteobacteria. *Biol. Fertil. Soils* **2012**, *48*, 295–303. [\[CrossRef\]](#)
41. Mudau, F.N.; Araya, H.T.; Du Toit, E.S.; Soundy, P.; Olivier, J. Bush Tea (*Athrixia Phyllicoides* DC.) as an Alternative Herbal and Medicinal Plant in Southern Africa: Opportunity for Commercialization—2007. Available online: <https://repository.up.ac.za/handle/2263/5852> (accessed on 18 December 2022).
42. Mudau, F.N.; Mogotlane, I.D.; Mashela, P.W.; Soundy, P. Seasonal Variation of Total Antioxidant Contents of Wild Bush Tea. *Acta Hort.* **2008**, *802*, 1–4. [\[CrossRef\]](#)
43. Mabogo, D.N.E. The Ethnobotany of Vhavenda. Ph.D. Thesis, University of Pretoria, Pretoria, Republic of South Africa, 1990.
44. Mudau, F.N.; Mariga, I.K. Bush tea as an herbal beverage and medicinal plant in South Africa. In *Tea Health and Disease Prevention*; Elsevier: Amsterdam, The Netherlands, 2013; pp. 183–189.
45. Araya, H.T. Seed Germination and Vegetative Propagation of Bush Tea (*Athrixia phyllicoides*). Ph.D. Thesis, University of Pretoria, Pretoria, South Africa, 2017.
46. Padayachee, K. The phytochemistry and biological activities of *Athrixia phyllicoides*. Master's Thesis, University Witwatersrand, Johannesburg, South Africa, 2011.
47. Mashimbye, M.J.; Mudau, F.N.; Soundy, P.; Van Ree, T. A new flavonol from *Athrixia phyllicoides* (bush tea). *S. Afr. J. Chem.* **2006**, *59*, 1–2.
48. Mavundza, E.J.; Tshikalange, T.E.; Lall, N.; Mudau, F.N.; Hussein, A.A. Antioxidant activity and cytotoxicity of three flavonoids from *Athrixia phyllicoides* ethanol extract. *S. Afr. J. Bot.* **2010**, *76*, 398. [\[CrossRef\]](#)
49. Mudau, F.N.; Soundy, P.; Du Toit, E.S.; Olivier, J. Variation in polyphenolic content of *Athrixia phyllicoides* (L.) (bush tea) leaves with season and nitrogen application. *S. Afr. J. Bot.* **2006**, *72*, 398–402. [\[CrossRef\]](#)
50. Nchabeleng, L.; Mudau, F.N.; Mariga, I.K. Effects of chemical composition of wild bush tea (*Athrixia phyllicoides* DC.) growing at locations differing in altitude, climate, and edaphic factors. *J. Med. Plants Res.* **2012**, *6*, 1662–1666. [\[CrossRef\]](#)
51. Tshivhandekano, I.; Ntushelo, K.; Ngezimana, W.; Tshikalange, T.E.; Mudau, F.N. Chemical compositions and antimicrobial activities of *Athrixia phyllicoides* DC. (bush tea), *Monsonia burkeana* (special tea) and synergistic effects of both combined herbal teas. *Asian Pac. J. Trop. Med.* **2014**, *7*, S448–S453. [\[CrossRef\]](#)
52. Nnzeru, L.R.; Ntushelo, K.; Mudau, F.N. Prevalence of *Bacillus* in the interior tissues of *Monsonia burkeana* and other medicinal plants in South Africa. *S. Afr. J. Bot.* **2017**, *113*, 19–22. [\[CrossRef\]](#)
53. Bachir Raho, G.; Benattouche, Z.; Bevilacqua, A.; Corbo, M.R.; Sinigaglia, M.; Pignatiello, S. Inhibitory effects of *Echinacea angustifolia* essential oils on the growth of five pathogenic organisms: *Poliform* spp.; *Pseudomonas* spp.; *Saccharomyces cerevisiae*, *Zygosaccharomyces bailii* and *Lactobacillus plantarum*. *Int. J. Adv. Res. Bot.* **2015**, *1*, 10–14.

54. Giles, J.T.; Palat III, C.T.; Chien, S.H.; Chang, Z.G.; Kennedy, D.T. Evaluation of echinacea for treatment of the common cold. *Pharmacother. J. Hum. Pharmacol. Drug Ther.* **2000**, *20*, 690–697. [CrossRef]
55. Hui, S.; Yan, H.; Qing, X.; Renyuan, Y.; Yongqiang, T. Isolation, characterization, and antimicrobial activity of endophytic bacteria from *Polygonum cuspidatum*. *Afr. J. Microbiol. Res.* **2013**, *7*, 1496–1504. [CrossRef]
56. Seo, W.T.; Lim, W.J.; Kim, E.J.; Yun, H.D.; Lee, Y.H.; Cho, K.M. Endophytic bacterial diversity in the young radish and their antimicrobial activity against pathogens. *J. Korean Soc. Appl. Biol. Chem.* **2010**, *53*, 493–503. [CrossRef]
57. Arunachalam, C.; Gayathri, P. Studies on bioprospecting of endophytic bacteria from the medicinal plant of *Andrographis paniculata* for their antimicrobial activity and antibiotic susceptibility pattern. *Int. J. Curr. Pharm. Res.* **2010**, *2*, 63–68.
58. Aravind, R.; Kumar, A.; Eapen, S.J.; Ramana, K.V. Endophytic bacterial flora in root and stem tissues of black pepper (*Piper nigrum* L.) genotype: Isolation, identification, and evaluation against *Phytophthora capsici*. *Lett. Appl. Microbiol.* **2009**, *48*, 58–64. [CrossRef]
59. Yang, R.X.; Zhang, S.W.; Xue, D.; Xuan, J.H.; Zhang, Y.B.; Peng, B.B. Culturable endophytes diversity isolated from and the genetic basis for their bioactivity. *Pol. J. Microbiol.* **2018**, *67*, 441–454. [CrossRef]
60. Chlebek, D.; Hupert-Kocurek, K. Endophytic bacteria in the phytodegradation of persistent organic pollutants. *Postępy Mikrobiol.-Adv. Microbiol.* **2019**, *58*, 70–79. [CrossRef]
61. Rakotoniriana, E.F.; Rafamantanana, M.; Randriamampionona, D.; Rabemanantsoa, C.; Urveg-Ratsimamanga, S.; El Jaziri, M.; Munaut, F.; Corbisier, A.M.; Quetin-Leclercq, J.; Declerck, S. Study in vitro of the impact of endophytic bacteria isolated from *Centella asiatica* on the disease incidence caused by the hemibiotrophic fungus *Colletotrichum higginsianum*. *Antonie Leeuwenhoek* **2013**, *103*, 121–133. [CrossRef] [PubMed]
62. Falcão, L.L.; Silva-Werneck, J.O.; Vilarinho, B.R.; Da Silva, J.P.; Pomella, A.W.V.; Marcellino, L.H. Antimicrobial and plant growth-promoting properties of the cacao endophyte *Bacillus subtilis* ALB 629. *J. Appl. Microbiol.* **2014**, *116*, 1584–1592. [CrossRef]
63. Dat, T.T.H.; Oanh, P.T.T.; Tam, V.T.T.; Anh, H.L.T. Antimicrobial and antioxidant activity of bacterial endophytes isolated from leaves of the mangrove plant *Rhizophora stylosa*. *Acad. J. Biol.* **2019**, *41*. [CrossRef]
64. Li, X.; Wang, X.; Wang, Y.; Liu, X.; Ren, X.; Dong, Y.; Ma, J.; Song, R.; Wei, J.; Yu, A.; et al. A systematic review on polysaccharides from *Dendrobium* genus: Recent advances in the preparation, structural characterization, bioactive molecular mechanisms, and applications. *Am. J. Chin. Med.* **2022**, *50*, 471–509. [CrossRef] [PubMed]
65. Sebola, T.E.; Uche-Okerefor, N.C.; Tapfuma, K.I.; Mekuto, L.; Green, E.; Mavumengwana, V. Evaluating antibacterial and anticancer activity of crude extracts of bacterial endophytes from *Crinum macowanii* Baker bulbs. *MicrobiologyOpen* **2019**, *8*, 1–10. [CrossRef] [PubMed]
66. Shukla, S.; Naik, G.; Mishra, S.K. Potential antimicrobial activity of bacterial endophytes isolated from *Flacourtia jangomas* (Lour.) Raeusch, a less explored medicinal plant. *J. Microbiol. Biotechnol. Food Sci.* **2021**, *4*, 473–477. [CrossRef]
67. Ahmed, H.; Shehu, S. Ethno-botanical and Pharmaceutical Properties of Mollucan Spinach (*Gynura procumbens* Lour. Merr.). *J. Appl. Sci. Environ. Manag.* **2022**, *26*, 1925–1935. [CrossRef]
68. Gupta, C.; Prakash, D.; Bakar, M.F.A.; Kitdamrongtham, W. Omic Route to Utilize Endophytes and Their Functional Potentials in Plant Growth Advancement. In *Plant Microbiome for Plant Productivity and Sustainable Agriculture*; Springer: Singapore, 2023; pp. 289–311.
69. Haque, E.; Kamal, M.S.; Tahsin, M.; Ahmed, R.; Choudhury, J.A.; Chowdhury, A.A.; Kabir, S.; Amran, M.; Uddin, M. Current knowledge regarding pharmacological profile and chemical constituents of *Gynura procumbens*. *Curr. Top. Med. Chem.* **2021**, *21*, 2671–2686. [CrossRef]
70. Solaiman, Z.M.; Anawar, H.M. Rhizosphere microbes' interactions in medicinal plants. In *Plant-Growth-Promoting Rhizobacteria (PGPR) and Medicinal Plants*; Springer: Cham, Switzerland, 2015; pp. 19–41.
71. Kumar, G.; Kanauija, N.; Bafana, A. Functional and phylogenetic diversity of root-associated bacteria of *Ajuga bracteosa* in Kangra valley. *Microbiol. Res.* **2012**, *167*, 220–225. [CrossRef]
72. Akinsanya, M.A.; Goh, J.K.; Lim, S.P.; Ting, A.S.Y. Diversity, antimicrobial and antioxidant activities of culturable bacterial endophyte communities in *Aloe vera*. *FEMS Microbiol. Lett.* **2015**, *362*, 1–8. [CrossRef] [PubMed]
73. Taechowisan, T.; Peberdy, J.F.; Lumyong, S. Isolation of endophytic actinomycetes from selected plants and their antifungal activity. *World J. Microbiol. Biotechnol.* **2003**, *19*, 381–385. [CrossRef]
74. El-Deeb, B.; Fayez, K.; Gherbawy, Y. Isolation and characterization of endophytic bacteria from *Plectranthus tenuiflorus* medicinal plant in Saudi Arabia desert and their antimicrobial activities. *J. Plant Interact.* **2012**, *8*, 56–64. [CrossRef]
75. Purity, K.; Vivienne, M.; Mary, N. Antimicrobial activities of secondary metabolites produced by endophytic bacteria from selected indigenous Kenyan plants. *Afr. J. Microbiol. Res.* **2012**, *6*, 7253–7258.
76. Egamberdieva, D.; Jabborova, D. Plant microbiome: Source for biologically active compounds. *Biodivers. Biomed.* **2020**, 1–9. [CrossRef]
77. Bhoonobong, A.; Sawadsitang, S.; Sodngam, S.; Mongkolthanaruk, W. Characterization of endophytic bacteria, *Bacillus amyloliquefaciens* for antimicrobial agents' production. *Int. Proc. Chem. Biol. Environ. Eng. (IPCBBE)* **2012**, *40*, 6–11.
78. Ebrahimi, A.; Asgharian, S.; Habibian, S. Antimicrobial Activities of Isolated Endophytes from Some Iranian Native Medicinal Plants. 2010. Available online: https://www.sid.ir/en/viewssid/j_pdf/106720100309.pdf (accessed on 21 December 2022).
79. Asrafal Islam, S.M.; Math, R.K.; Kim, J.M.; Yun, M.G.; Cho, J.J.; Kim, E.J.; Lee, Y.H.; Yun, H.D. Effect of plant age on endophytic bacterial diversity of balloon flower (*Platycodon grandiflorum*) root and their antimicrobial activities. *Curr. Microbiol.* **2010**, *61*, 346–356. [CrossRef] [PubMed]

80. Pal, A.; Chattopadhyay, A.; Paul, A.K. Diversity and antimicrobial spectrum of endophytic bacteria isolated from *Paederia foetida* L. *Int. J. Curr. Pharm. Res.* **2012**, *4*, 123–127.
81. Guan, S.H.; Sattler, I.; Lin, W.H.; Guo, D.A.; Grabley, S. p-Aminoacetophenonic Acids Produced by a Mangrove Endophyte: *Streptomyces g. riseus* subsp. *J. Nat. Prod.* **2005**, *68*, 1198–1200. [[CrossRef](#)]
82. Strobel, G.; Daisy, B.; Castillo, U.; Harper, J. Natural products from endophytic microorganisms. *J. Nat. Prod.* **2004**, *67*, 257–268. [[CrossRef](#)] [[PubMed](#)]
83. Castillo, U.F.; Strobel, G.A.; Mullenberg, K.; Condrón, M.M.; Teplow, D.B.; Folgiano, V.; Gallo, M.; Ferracane, R.; Mannina, L.; Viel, S.; et al. Munumbicins E-4 and E-5: Novel broad-spectrum antibiotics from *Streptomyces* NRRL 3052. *FEMS Microbiol. Lett.* **2006**, *255*, 296–300. [[CrossRef](#)] [[PubMed](#)]
84. Puri, A. Plant Growth Promotion and Nitrogen Fixation by *Paenibacillus Polymyxa* in Corn and Canola. Ph.D. Thesis, University of British Columbia, Vancouver, BC, Canada, 2015.
85. Ezra, D.; Castillo, U.F.; Strobel, G.A.; Hess, W.M.; Porter, H.; Jensen, J.B.; Condrón, M.A.; Teplow, D.B.; Sears, J.; Maranta, M.; et al. Coronamycins, peptide antibiotics produced by a verticillate *Streptomyces* sp. (MSU-2110) endophytic on *Monstera* sp. *Microbiology* **2004**, *150*, 785–793. [[CrossRef](#)]
86. Pandey, P.K.; Singh, S.; Singh, M.C.; Singh, A.K.; Yadav, S.K.; Pandey, A.K.; Heisnam, P. Diversity, ecology, and conservation of fungal and bacterial endophytes. In *Microbial Resource Conservation*; Springer: Cham, Switzerland, 2018; pp. 393–430.
87. Ding, L.; Maier, A.; Fiebig, H.H.; Lin, W.H.; Hertweck, C. A family of multicyclic indolosesquiterpenes from a bacterial endophyte. *Org. Biomol. Chem.* **2011**, *9*, 4029–4031. [[CrossRef](#)]
88. Ding, L.; Münch, J.; Goerls, H.; Maier, A.; Fiebig, H.H.; Lin, W.H.; Hertweck, C. Xiamycin, a pentacyclic indolosesquiterpene with selective anti-HIV activity from a bacterial mangrove endophyte. *Bioorganic Med. Chem. Lett.* **2010**, *20*, 6685–6687. [[CrossRef](#)] [[PubMed](#)]
89. Qin, S.; Li, J.; Chen, H.H.; Zhao, G.Z.; Zhu, W.Y.; Jiang, C.L.; Xu, L.H.; Li, W.J. Isolation, diversity, and antimicrobial activity of rare actinobacteria from medicinal plants of tropical rain forests in Xishuangbanna, China. *Appl. Environ. Microbiol.* **2009**, *75*, 6176–6186. [[CrossRef](#)]
90. Hu, H.Q.; Li, X.S.; He, H. Characterization of an antimicrobial material from a newly isolated *Bacillus amyloliquefaciens* from mangrove for biocontrol of *Capsicum* bacterial wilt. *Biol. Control.* **2010**, *54*, 359–365. [[CrossRef](#)]
91. Kumaravel, S.; Ranganathan, R. Survey of mangroves and their associates in pichavaram mangrove forest. *Int. J. Sci. Invent. Today.* **2018**, *7*, 176–182.
92. Soni, R.; Nanjani, S.; Keharia, H. Genome analysis reveals probiotic propensities of *Paenibacillus polymyxa* HK4. *Genomics* **2021**, *113*, 861–873. [[CrossRef](#)] [[PubMed](#)]
93. Song, C.Z.; Chen, X.W.; Chen, D.H. Research progress on endophytes in medicinal plant *Artemisia annua*. *Biotechnol. Bull.* **2016**, *32*, 1.
94. Verma, V.C.; Gond, S.K.; Kumar, A.; Mishra, A.; Kharwar, R.N.; Gange, A.C. Endophytic actinomycetes from *Azadirachta indica* A. Juss.: Isolation, diversity, and anti-microbial activity. *Microb. Ecol.* **2009**, *57*, 749–756. [[CrossRef](#)] [[PubMed](#)]
95. Han, J.; Song, Y.; Liu, Z.; Hu, Y. Culturable bacterial community analysis in the root domains of two varieties of tree peony (*Paeonia ostii*). *FEMS Microbiol. Lett.* **2011**, *322*, 15–24. [[CrossRef](#)]
96. Young, M.K.; Chong, K.L.; Kye, M.C. Diversity and antimicrobial activity of isolated endophytic bacteria from *Deodeok* (*Codonopsis lanceolata*) of different locations and ages. *Afr. J. Microbiol. Res.* **2013**, *7*, 1015–1028.
97. Ma, L.; Cao, Y.H.; Cheng, M.H.; Huang, Y.; Mo, M.H.; Wang, Y.; Yang, J.Z.; Yang, F.X. Phylogenetic diversity of bacterial endophytes of *Panax notoginseng* with antagonistic characteristics towards pathogens of root-rot disease complex. *Antonie Leeuwenhoek* **2013**, *103*, 299–312. [[CrossRef](#)]
98. Sultan, R.A.; Mahmood, S.B.Z.; Azhar, I.; Ahmed, S.W.; Mahmood, Z.A. Biological activities assessment of *Centella asiatica* (Linn.). *J. Herbs Spices Med. Plants* **2014**, *20*, 319–327. [[CrossRef](#)]
99. Shurigin, V.; Davranov, K.; Wirth, S.; Egamberdieva, D.; Bellingrath-Kimura, S.D. Medicinal plants with phytotoxic activity harbour endophytic bacteria with plant growth inhibitory properties. *Environ. Sustain.* **2018**, *1*, 209–215. [[CrossRef](#)]
100. Kan, F.L.; Chen, Z.Y.; Wang, E.T.; Tian, C.F.; Sui, X.H.; Chen, W.X. Characterization of symbiotic and endophytic bacteria isolated from root nodules of herbaceous legumes grown in Qinghai–Tibet plateau and in other zones of China. *Arch. Microbiol.* **2007**, *188*, 103–115. [[CrossRef](#)] [[PubMed](#)]
101. Saleem, M.; Karim, M.; Qadir, M.I.; Ahmed, B.; Rafiq, M.; Ahmad, B. In vitro antibacterial activity and phytochemical analysis of hexane extract of *Vicia sativa*. *Bangladesh J. Pharmacol.* **2014**, *9*, 189–193. [[CrossRef](#)]
102. Jia, X.; Liu, Y.; Wang, S.; Ma, J.; Yu, J.; Yue, X.; Zhang, Y.; Wang, X. Screening of metabolic markers present in *Oxytropis* by UHPLC-Q-TOF/MS and preliminary pharmacophylogenetic. *Front. Plant Sci.* **2022**, *13*, 958460. [[CrossRef](#)] [[PubMed](#)]
103. Krakowska, A.; Rafińska, K.; Walczak, J.; Buszewski, B. Enzyme-assisted optimized supercritical fluid extraction to improve *Medicago sativa* polyphenolics isolation. *Ind. Crops Prod.* **2018**, *124*, 931–940. [[CrossRef](#)]
104. Chang, Y.L.; Wang, E.T.; Sui, X.H.; Zhang, X.X.; Chen, W.X. Molecular diversity and phylogeny of rhizobia associated with *Lablab purpureus* (Linn.) grown in Southern China. *Syst. Appl. Microbiol.* **2011**, *34*, 276–284. [[CrossRef](#)] [[PubMed](#)]
105. Anwer, M.S.; Shamim, S.; Ahmed, S.; Hasan, M.M.; Azhar, I. Hypotensive activity of *Melilotus officinalis* (L.) Pallas. *Eur. J. Medicine. Ser. B.* **2015**, *3*, 80–85. [[CrossRef](#)]

106. Hayot Carbonero, C.; Carbonero, F.; Smith, L.M.; Brown, T.A. Phylogenetic characterization of *Onobrychis* species with special focus on the forage crop *Onobrychis viciifolia* Scop. *Genet. Resour. Crop Evol.* **2012**, *59*, 1777–1788. [\[CrossRef\]](#)
107. Al-Snafi, A.E. The pharmacology and medical importance of *Dolichos lablab* (*Lablab purpureus*)-A review. *IOSR J. Pharm.* **2017**, *7*, 22–30. [\[CrossRef\]](#)
108. Hossain, S.; Ahmed, R.; Bhowmick, S.; Mamun, A.A.; Hashimoto, M. Proximate composition, and fatty acid analysis of *Lablab purpureus* (L.) legume seed: Implicates to both protein and essential fatty acid supplementation. *SpringerPlus* **2016**, *5*, 1–10. [\[CrossRef\]](#)
109. Saha, L.; Tiwari, J.; Baudh, K.; Ma, Y. Recent developments in microbe–plant-based bioremediation for tackling heavy metal-polluted soils. *Front. Microbiol.* **2021**, *12*.
110. Li, M.; Li, Y.; Chen, W.F.; Sui, X.H.; Li Jr, Y.; Li, Y.; Wang, E.T.; Chen, W.X. Genetic diversity, community structure and distribution of rhizobia in the root nodules of *Caragana* spp. from arid and semi-arid alkaline deserts, in the north of China. *Syst. Appl. Microbiol.* **2012**, *35*, 239–245. [\[CrossRef\]](#)
111. Dai, J.X.; Liu, X.M.; Wang, Y.J. Diversity of endophytic bacteria in *Caragana microphylla* grown in the desert grassland of the Ningxia Hui autonomous region of China. *Genet. Mol. Res.* **2014**, *13*, 2349–2358. [\[CrossRef\]](#) [\[PubMed\]](#)
112. Jishtu, V.; Goraya, G.S. Leguminosae (nom. alt. Fabaceae)—Its Diversity, Use and Role in Environmental Conservation in the Harsh Environs of the Cold Deserts of North-West India. In *The Plant Family Fabaceae*; Springer: Singapore, 2020; pp. 261–285.
113. Yasseen, B.T.; Al-Thani, R.F. Endophytes and halophytes to remediate industrial wastewater and saline soils: Perspectives from Qatar. *Plants* **2022**, *11*, 1497. [\[CrossRef\]](#) [\[PubMed\]](#)
114. Jha, B.; Gontia, I.; Hartmann, A. The roots of the halophyte *Salicornia brachiata* are a source of new halotolerant diazotrophic bacteria with plant growth-promoting potential. *Plant Soil* **2012**, *356*, 265–277. [\[CrossRef\]](#)
115. Pandey, P.; Kang, S.C.; Maheshwari, D.K. Isolation of endophytic plant growth promoting *Burkholderia* sp. MSSP from root nodules of *Mimosa pudica*. *Curr. Sci.* **2005**, *89*, 177–180.
116. Patil, S.V.; Mohite, B.V.; Patil, C.D.; Koli, S.H.; Borase, H.P.; Patil, V.S. Azotobacter. In *Beneficial Microbes in Agro-Ecology*; Academic Press: Cambridge, MA, USA, 2020; pp. 397–426.
117. Benhizia, Y.; Benhizia, H.; Benguedouar, A.; Muresu, R.; Giacomini, A.; Squartini, A. Gamma proteobacteria can nodulate legumes of the genus *Hedysarum*. *Syst. Appl. Microbiol.* **2004**, *27*, 462–468. [\[CrossRef\]](#)
118. Van Berkum, P.; Beyene, D.; Bao, G.; Campbell, T.A.; Eardly, B. *DRhizobium mongolense* sp. nov. is one of three rhizobial genotypes identified which nodulate and form nitrogen-fixing symbioses with *Medicago ruthenica* [(L.) Ledebour]. *Int. J. Syst. Evol. Microbiol.* **1998**, *48*, 13–22.
119. Zakhia, F.; Jeder, H.; Domergue, O.; Willems, A.; Cleyet-Marel, J.C.; Gillis, M.; Dreyfus, B.; De Lajudie, P. Characterisation of wild legume nodulating bacteria (LNB) in the infra-arid zone of Tunisia. *Syst. Appl. Microbiol.* **2004**, *27*, 380–395. [\[CrossRef\]](#)
120. Wang, E.T.; Van Berkum, P.; Beyene, D.; Sui, X.H.; Dorado, O.; Chen, W.X.; Martínez-Romero, E. *Rhizobium huaatlense* sp. nov.; a symbiont of *Sesbania herbacea* that has a close phylogenetic relationship with *Rhizobium galegae*. *Int. J. Syst. Evol. Microbiol.* **1998**, *48*, 687–699. [\[CrossRef\]](#)
121. Wei, G.H.; Wang, E.T.; Tan, Z.Y.; Zhu, M.E.; Chen, W.X. *Rhizobium indigoferae* sp. nov. and *Sinorhizobium kummerowiae* sp. nov.; Respectively isolated from *Indigofera* spp. and *Kummerowia stipulacea*. *Int. J. Syst. Evol. Microbiol.* **2002**, *52*, 2231–2239.
122. Squartini, A.; Struffi, P.; Döring, H.; Selenska-Pobell, S.; Tola, E.; Giacomini, A.; Vendramin, E.; Velázquez, E.; Mateos, P.F.; Martínez-Molina, E.; et al. *Rhizobium sullae* sp. nov. (formerly '*Rhizobium hedysari*'), the root-nodule microsymbiont of *Hedysarum coronarium* L. *Int. J. Syst. Evol. Microbiol.* **2002**, *52*, 1267–1276. [\[PubMed\]](#)
123. Tan, Z.Y.; Kan, F.L.; Peng, G.X.; Wang, E.T.; Reinhold-Hurek, B.; Chen, W.X. *Rhizobium yanglingense* sp. nov.; isolated from arid and semi-arid regions in China. *Int. J. Syst. Evol. Microbiol.* **2001**, *51*, 909–914. [\[CrossRef\]](#)
124. Nick, G.; De Lajudie, P.; Eardly, B.D.; Suomalainen, S.; Paulin, L.; Zhang, X.; Gillis, M.; Lindström, K. *Sinorhizobium arboris* sp. nov. and *Sinorhizobium kostiense* sp. nov.; Isolated from leguminous trees in Sudan and Kenya. *Int. J. Syst. Evol. Microbiol.* **1999**, *49*, 1359–1368. [\[CrossRef\]](#)
125. Wang, E.T.; Tan, Z.Y.; Willems, A.; Fernández-López, M.; Reinhold-Hurek, B.; Martínez-Romero, E. *Sinorhizobium morelense* sp. nov.; a *Leucaena leucocephala*-associated bacterium that is highly resistant to multiple antibiotics. *Int. J. Syst. Evol. Microbiol.* **2002**, *52*, 1687–1693. [\[PubMed\]](#)
126. De Lajudie, P.; Laurent-Fulele, E.; Willems, A.; Torek, U.; Coopman, R.; Collins, M.D.; Kersters, K.; Dreyfus, B.; Gillis, M. *Allorhizobium undicola* gen. nov.; sp. nov.; nitrogen-fixing bacteria that efficiently nodulate *Neptunia natans* in Senegal. *Int. J. Syst. Evol. Microbiol.* **1998**, *48*, 1277–1290. [\[CrossRef\]](#) [\[PubMed\]](#)
127. Wang, E.T.; Van Berkum, P.; Sui, X.H.; Beyene, D.E.S.T.A.; Chen, W.X.; Martínez-Romero, E. Diversity of rhizobia associated with *Amorpha fruticosa* isolated from Chinese soils and description of *Mesorhizobium amorphae* sp. nov. *Int. J. Syst. Evol. Microbiol.* **1999**, *49*, 51–65. [\[CrossRef\]](#)
128. Velázquez, E.; Igual, J.M.; Willems, A.; Fernández, M.P.; Muñoz, E.; Mateos, P.F.; Abril, A.; Toro, N.; Normand, P.; Cervantes, E.; et al. *Mesorhizobium chacoense* sp. nov.; a novel species that nodulates *Prosopis alba* in the Chaco Arido region (Argentina). *Int. J. Syst. Evol. Microbiol.* **2001**, *51*, 1011–1021. [\[CrossRef\]](#)
129. Rivas, R.; Velázquez, E.; Willems, A.; Vizcaino, N.; Subba-Rao, N.S.; Mateos, P.F.; Gillis, M.; Dazzo, F.B.; Martínez-Molina, E. A new species of *Devosia* that forms a unique nitrogen-fixing root-nodule symbiosis with the aquatic legume *Neptunia natans* (Lf) Druce. *Appl. Environ. Microbiol.* **2002**, *68*, 5217–5222. [\[CrossRef\]](#) [\[PubMed\]](#)

130. Rivas, R.; Willems, A.; Subba-Rao, N.S.; Mateos, P.F.; Dazzo, F.B.; Kroppenstedt, R.M.; Martínez-Molina, E.; Gillis, M.; Velázquez, E. Description of *Devosia neptuniae* sp. nov. that nodulates and fixes nitrogen in symbiosis with *Neptunia natans*, an aquatic legume from India. *Syst. Appl. Microbiol.* **2003**, *26*, 47–53. [\[CrossRef\]](#)
131. Yao, Z.Y.; Kan, F.L.; Wang, E.T.; Wei, G.H.; Chen, W.X. Characterization of rhizobia that nodulate legume species of the genus *Lespedeza* and description of *Bradyrhizobium yuanmingense* sp. nov. *Int. J. Syst. Evol. Microbiol.* **2002**, *52*, 2219–2230. [\[PubMed\]](#)
132. Chen, W.M.; Laevens, S.; Lee, T.M.; Coenye, T.; De Vos, P.; Mergeay, M.; Vandamme, P. *Ralstonia taiwanensis* sp. nov.; isolated from root nodules of *Mimosa* species and sputum of a cystic fibrosis patient. *Int. J. Syst. Evol. Microbiol.* **2001**, *51*, 1729–1735. [\[CrossRef\]](#)
133. Zhang, X.G.; Li, X.R.; Wang, Q.L.; Wang, W.N.; Chen, X.Q. Study on effects of endophytes on growth and production of Z-Ligustilide and ferulic acid in *Angelica sinensis*. *Braz. J. Bot.* **2016**, *39*, 417–426. [\[CrossRef\]](#)
134. Čeksterytė, V.; Navakauskienė, R.; Treigytė, G.; Jansen, E.; Kurtinaitienė, B.; Dabkevičienė, G.; Balžekas, J. Fatty acid profiles of monofloral clover beebread and pollen and proteomics of red clover (*Trifolium pratense*) pollen. *Biosci. Biotechnol. Biochem.* **2016**, *80*, 2100–2108. [\[CrossRef\]](#) [\[PubMed\]](#)
135. Sturz, A.V.; Christie, B.R.; Matheson, B.G. Associations of bacterial endophyte populations from red clover and potato crops with potential for beneficial allelopathy. *Can. J. Microbiol.* **1998**, *44*, 162–167. [\[CrossRef\]](#)
136. Sturz, A.V.; Christie, B.R.; Matheson, B.G.; Nowak, J. Biodiversity of endophytic bacteria which colonize red clover nodules, roots, stems and foliage and their influence on host growth. *Biol. Fertil. Soils* **1997**, *25*, 13–19. [\[CrossRef\]](#)
137. Etesami, H.; Mirsyedhosseini, H.; Alikhani, H.A. Rapid screening of berseem clover (*Trifolium alexandrinum*) endophytic bacteria for rice plant seedlings growth-promoting agents. *Int. Sch. Res. Not. Int. Sch. Res. Not.* **2013**, *2013*, 371879. [\[CrossRef\]](#)
138. Eswaraiah, G.; Peele, K.A.; Krupanidhi, S.; Kumar, R.B.; Venkateswarulu, T.C. Studies on phytochemical, antioxidant, antimicrobial analysis, and separation of bioactive leads of leaf extract from the selected mangroves. *J. King Saud Univ. -Sci.* **2020**, *32*, 842–847. [\[CrossRef\]](#)
139. Ye, D.; Li, T.; Yu, H.; Zou, L.; Huang, H.; Zhang, X.; Liu, J. Characteristics of bacterial community in root-associated soils of the mining ecotype of *Polygonum hydropiper*, a P-accumulating herb. *Appl. Soil Ecol.* **2020**, *150*, 1–9. [\[CrossRef\]](#)
140. Tariq, M.; Naveed, A.; Barkat, A.K. The morphology, characteristics, and medicinal properties of *Camellia sinensis* tea. *J. Med. Plants Res.* **2010**, *4*, 2028–2033. [\[CrossRef\]](#)
141. Negukhula, S.; Mudau, F.N.; Mariga, I.K.; Liphadzi, K.B. Effects of soaking conditions on total phenolic and antioxidant activity of black tea and black tea combined (50:50) with bush tea. *Indian J. Hortic.* **2011**, *68*, 91–95.
142. Varmazyari, A.; Çakmakçı, R. Diversity and metabolic potential of the dominant culturable N₂-fixing and P-solubilising bacteria from tea (*Camellia sinensis* L.) rizosphere. *Front. Environ. Microbiol.* **2018**, *4*, 45–54. [\[CrossRef\]](#)
143. Archana, S.; Abraham, J. Comparative analysis of antimicrobial activity of leaf extracts from fresh green tea, commercial green tea, and black tea on pathogens. *J. Appl. Pharm. Sci.* **2011**, *1*, 149–152.
144. Mandal, S.; DebMandal, M.; Pal, N.K.; Saha, K. Inhibitory and killing activities of black tea (*Camellia sinensis*) extract against *Salmonella enterica* serovar Typhi and *Vibrio cholerae* O1 biotype El Tor serotype Ogawa isolates. *Jundishapur J. Microbiol.* **2011**, *4*, 115–121.
145. Ho, Y.N.; Mathew, D.C.; Hsiao, S.C.; Shih, C.H.; Chien, M.F.; Chiang, H.M.; Huang, C.C. Selection, and application of endophytic bacterium *Achromobacter xylosoxidans* strain F3B for improving phytoremediation of phenolic pollutants. *J. Hazard. Mater.* **2012**, *219*, 43–49. [\[CrossRef\]](#) [\[PubMed\]](#)
146. Mbata, T.I. Preliminary studies of the antibacterial activities of processed Kenyan and Nigerian tea. *Afr. J. Biotechnol.* **2007**, *6*, 278–279.
147. Rozoy, E.; Bazinet, L.; Araya-Farias, M.; Guernec, A.; Saucier, L. Inhibitory effects of commercial and enriched green tea extracts on the growth of *Brochothrix thermosphacta*, *Pseudomonas putida* and *Escherichia coli*. *J. Food Res.* **2013**, *2*, 1–7. [\[CrossRef\]](#)
148. Vasudeo, Z.; Sonika, B. Antimicrobial activity of tea (*Camellia sinensis*). *Biomed. Pharmacol. J.* **2009**, *2*, 173.
149. Hamilton-Miller, J.M.T. Anti-cariogenic properties of tea (*Camellia sinensis*). *J. Med. Microbiol.* **2001**, *50*, 299–302. [\[CrossRef\]](#) [\[PubMed\]](#)
150. Dong, F.; Yang, Z.; Baldermann, S.; Sato, Y.; Asai, T.; Watanabe, N. Herbivore-induced volatiles from tea (*Camellia sinensis*) plants and their involvement in intraplant communication and changes in endogenous nonvolatile metabolites. *J. Agric. Food Chem.* **2011**, *59*, 13131–13135. [\[CrossRef\]](#)
151. Hara-Kudo, Y.; Yamasaki, A.; Sasaki, M.; Okubo, T.; Minai, Y.; Haga, M.; Kondo, K.; Sugita-Konishi, Y. Antibacterial action on pathogenic bacterial spore by green tea catechins. *J. Sci. Food Agric.* **2005**, *85*, 2354–2361. [\[CrossRef\]](#)
152. Kumar, A.; Kumar, A.; Thakur, P.; Patil, S.; Payal, C.; Kumar, A.; Sharma, P. Antibacterial activity of green tea (*Camellia sinensis*) extracts against various bacteria isolated from environmental sources. *Recent Res. Sci. Technol.* **2012**, *4*, 19–23.
153. Aeon, A.; Maheshwari, D.K.; Meena, V.S. Endophytic bacteria promote growth of the medicinal legume *Clitoria ternatea* L. by chemotactic activity. *Arch. Microbiol.* **2020**, *202*, 1049–1058.
154. Gupta, M.; Kiran, S.; Gulati, A.; Singh, B.; Tewari, R. Isolation and identification of phosphate solubilizing bacteria able to enhance the growth and aloin-A biosynthesis of *Aloe barbadensis* Miller. *Microbiol. Res.* **2012**, *167*, 358–363. [\[CrossRef\]](#)
155. Juneby, H. *B Aloe barbadensis*—A legendary medicinal plant. *Pharmacognosy* **2009**, *15*, 1–14.
156. Ye, D.; Li, T.; Yi, Y.; Zhang, X.; Zou, L. Characteristics of endophytic fungi from *Polygonum hydropiper* suggest potential application for P-phytoextraction. *Fungal Ecol.* **2019**, *41*, 126–136. [\[CrossRef\]](#)

157. Sharma, H.; Rai, A.K.; Dahiya, D.; Chettri, R.; Nigam, P.S. Exploring endophytes for in vitro synthesis of bioactive compounds similar to metabolites produced in vivo by host plants. *AIMS Microbiol.* **2021**, *7*, 175. [\[CrossRef\]](#)
158. Taghavi, S.; Garafola, C.; Monchy, S.; Newman, L.; Hoffman, A.; Weyens, N.; Barac, T.; Vangronsveld, J.; van der Lelie, D. Genome survey and characterization of endophytic bacteria exhibiting a beneficial effect on growth and development of poplar trees. *Appl. Environ. Microbiol.* **2009**, *75*, 748–757. [\[CrossRef\]](#)
159. Braga, N.R.; Vieira, C. Effect of *Bradyrhizobium* sp.; nitrogen, molybdenum, and other micronutrients on the chickpea yield. *Bragantia* **1998**, *57*, 349–353. [\[CrossRef\]](#)
160. Parul, B.; Chandra, R. Interaction of *Mesorhizobium icero* and rhizospheric bacteria on nodulation, growth, and yield of chickpea. *J. Food Legumes* **2009**, *22*, 137–139.
161. Datta, C.; Basu, P.S. Indole acetic acid production by a *Rhizobium* species from root nodules of a leguminous shrub, *Cajanus cajan*. *Microbiol. Res.* **2000**, *155*, 123–127. [\[CrossRef\]](#)
162. Gupta, A.; Saxena, A.K.; Gopal, M.; Tilak, K.V.B.R. Effects of co-inoculation of plant growth promoting rhizobacteria and *Bradyrhizobium* sp. (Vigna) on growth and yield of green gram [*Vigna radiata* (L.) Wilczek]. *Trop. Agric.-Lond. Trinidad* **2003**, *80*, 28–35.
163. Sy, A.; Giraud, E.; Jourand, P.; Garcia, N.; Willems, A.; De Lajudie, P.; Prin, Y.; Neyra, M.; Gillis, M.; Boivin-Masson, C.; et al. Methylophilic *Methylobacterium* bacteria nodulate and fix nitrogen in symbiosis with legumes. *J. Bacteriol.* **2001**, *183*, 214–220. [\[CrossRef\]](#)
164. Silva, C.F.D.; Vitorino, L.C.; Mendonça, M.A.C.; Araújo, W.L.; Dourado, M.N.; Albuquerque, L.C.; Soares, M.A.; Souchie, E.L. Screening of plant growth-promoting endophytic bacteria from the roots of the medicinal plant *Aloe vera*. *S. Afr. J. Bot.* **2020**, *134*, 3–16. [\[CrossRef\]](#)
165. Pongsilp, N. Classification and Taxonomy of Rhizobia. In *Phenotypic and Genotypic Diversity of Rhizobia*; Bentham Science Publishers: Potomac, MD, USA, 2012.
166. Sindhu, S.S.; Jangu, O.P.; Sivaramaiah, N. Genetic engineering of diazotrophic bacteria to improve nitrogen fixation for sustainable agriculture. In *Biotechnology Emerging Trends*; Scientific Publishers: Jodhpur, India, 2009; pp. 73–112.
167. Wang, E.T.; Rogel, M.A.; García-De Los Santos, A.; Martínez-Romero, J.; Cevallos, M.A.; Martínez-Romero, E. *Rhizobium etli* bv. *mimosae*, a novel biovar isolated from *Mimosa affinis*. *Int. J. Syst. Evol. Microbiol.* **1999**, *49*, 1479–1491. [\[CrossRef\]](#)
168. Moreira, F.M.S. 11 Nitrogen-fixing Leguminosae-nodulating Bacteria. *Soil Biodivers. Amazon. Other Braz. Ecosyst.* **2006**, 237–280.
169. Gupta, C.P.; Kumar, B.; Dubey, R.C.; Maheshwari, D.K. Chitinase-mediated destructive antagonistic potential of *Pseudomonas aeruginosa* GRC1 against *Sclerotinia sclerotiorum* causing stem rot of peanut. *BioControl* **2006**, *51*, 821–835. [\[CrossRef\]](#)
170. Kumar, K.V.; Srivastava, S.; Singh, N.; Behl, H.M. Role of metal resistant plant growth promoting bacteria in ameliorating fly ash to the growth of *Brassica juncea*. *J. Hazard. Mater.* **2009**, *170*, 51–57. [\[CrossRef\]](#)
171. Shi, P.; Zhu, K.; Zhang, Y.; Chai, T. Growth and cadmium accumulation of *Solanum nigrum* L. seedling were enhanced by heavy metal-tolerant strains of *Pseudomonas aeruginosa*. *Water Air Soil Pollut.* **2016**, *227*, 1–11. [\[CrossRef\]](#)
172. Ullah, A.; Heng, S.; Munis, M.F.H.; Fahad, S.; Yang, X. Phytoremediation of heavy metals assisted by plant growth promoting (PGP) bacteria: A review. *Environ. Exp. Bot.* **2015**, *117*, 28–40. [\[CrossRef\]](#)
173. Chaudhary, D.R. Halophytes of Semi-Arid Areas: Resources for Mitigation of Climate Change. In *Climate Change Adaptations in Dryland Agriculture in Semi-Arid Areas*; Springer: Singapore, 2022; pp. 93–109.
174. El-Tarabily, K.A.; Youssef, T. Improved growth performance of the mangrove *Avicennia marina* seedlings using a 1-aminocyclopropane-1-carboxylic acid deaminase-producing isolate of *Pseudoalteromonas maricaloris*. *Plant Growth Regul.* **2011**, *65*, 473–483. [\[CrossRef\]](#)
175. Li, H.Y.; Wei, D.Q.; Shen, M.; Zhou, Z.P. Endophytes, and their role in phytoremediation. *Fungal Divers.* **2012**, *54*, 11–18. [\[CrossRef\]](#)
176. Dary, M.; Chamber-Pérez, M.A.; Palomares, A.J.; Pajuelo, E. “In situ” phytostabilisation of heavy metal polluted soils using *Lupinus luteus* inoculated with metal resistant plant-growth promoting rhizobacteria. *J. Hazard. Mater.* **2010**, *177*, 323–330. [\[CrossRef\]](#) [\[PubMed\]](#)
177. Abou-Shanab, R.A.I.; Angle, J.S.; Chaney, R.L. Bacterial inoculants affecting nickel uptake by *Alyssum murale* from low, moderate, and high Ni soils. *Soil Biol. Biochem.* **2006**, *38*, 2882–2889. [\[CrossRef\]](#)
178. Wu, S.C.; Cheung, K.C.; Luo, Y.M.; Wong, M.H. Effects of inoculation of plant growth-promoting rhizobacteria on metal uptake by *Brassica juncea*. *Environ. Pollut.* **2006**, *140*, 124–135. [\[CrossRef\]](#)
179. Zaidi, S.; Usmani, S.; Singh, B.R.; Musarrat, J. Significance of *Bacillus subtilis* strain SJ-101 as a bioinoculant for concurrent plant growth promotion and nickel accumulation in *Brassica juncea*. *Chemosphere* **2006**, *64*, 991–997. [\[CrossRef\]](#)
180. Ahemad, M.; Khan, M.S. Evaluation of plant-growth-promoting activities of rhizobacterium *Pseudomonas putida* under herbicide stress. *Ann. Microbiol.* **2012**, *62*, 1531–1540. [\[CrossRef\]](#)
181. Sheng, X.F.; Xia, J.J.; Jiang, C.Y.; He, L.Y.; Qian, M. Characterization of heavy metal-resistant endophytic bacteria from rape (*Brassica napus*) roots and their potential in promoting the growth and lead accumulation of rape. *Environ. Pollut.* **2008**, *156*, 1164–1170. [\[CrossRef\]](#) [\[PubMed\]](#)
182. Unterbrunner, R.; Puschenreiter, M.; Sommer, P.; Wieshammer, G.; Tlustos, P.; Zupan, M.; Wenzel, W.W. Heavy metal accumulation in trees growing on contaminated sites in Central Europe. *Environ. Pollut.* **2007**, *148*, 107–114. [\[CrossRef\]](#) [\[PubMed\]](#)
183. Wani, P.A.; Khan, M.S.; Zaidi, A. Effect of metal tolerant plant growth promoting *Bradyrhizobium* sp.(vigna) on growth, symbiosis, seed yield and metal uptake by greengram plants. *Chemosphere* **2007**, *70*, 36–45. [\[CrossRef\]](#)

184. Mitter, E.K.; de Freitas, J.R.; Germida, J.J. Hydrocarbon-degrading genes in root endophytic communities on oil sands reclamation covers. *Int. J. Phytoremediation* **2020**, *22*, 703–712. [\[CrossRef\]](#)
185. Shin, M.N.; Shim, J.; You, Y.; Myung, H.; Bang, K.S.; Cho, M.; Kamala-Kannan, S.; Oh, B.T. Characterization of lead resistant endophytic *Bacillus* sp. MN3-4 and its potential for promoting lead accumulation in metal hyperaccumulator *Alnus firma*. *J. Hazard. Mater.* **2012**, *199*, 314–320. [\[PubMed\]](#)
186. Lodewyckx, C.; Mergeay, M.; Vangronsveld, J.; Clijsters, H.; Van Der Lelie, D. Isolation, characterization, and identification of bacteria associated with the zinc hyperaccumulator *Thlaspi caerulescens* subsp. *calaminaria*. *Int. J. Phytoremediation* **2002**, *4*, 101–115. [\[CrossRef\]](#) [\[PubMed\]](#)
187. Idris, R.; Trifonova, R.; Puschenreiter, M.; Wenzel, W.W.; Sessitsch, A. Bacterial communities associated with flowering plants of the Ni hyperaccumulator *Thlaspi goesingense*. *Appl. Environ. Microbiol.* **2004**, *70*, 2667–2677. [\[CrossRef\]](#) [\[PubMed\]](#)
188. Sun, R.L.; Zhou, Q.X.; Sun, F.H.; Jin, C.X. Antioxidative defense and proline/phytochelatin accumulation in a newly discovered Cd-hyperaccumulator, *Solanum nigrum* L. *Environ. Exp. Bot.* **2007**, *60*, 468–476. [\[CrossRef\]](#)
189. Khan, A.R.; Park, G.S.; Asaf, S.; Hong, S.J.; Jung, B.K.; Shin, J.H. Complete genome analysis of *Serratia marcescens* RSC-14: A plant growth-promoting bacterium that alleviates cadmium stress in host plants. *PLoS ONE* **2017**, *12*, e0171534. [\[CrossRef\]](#)
190. Mengoni, A.; Pini, F.; Bazzicalupo, M. Bacterial flora of the nickel-hyperaccumulator plant *Alyssum bertolonii*. In *Biomangement of Metal-Contaminated Soils*; Springer: Dordrecht, The Netherlands, 2011; pp. 167–181.
191. Chen, W.M.; Wu, C.H.; James, E.K.; Chang, J.S. Metal biosorption capability of *Cupriavidus taiwanensis* and its effects on heavy metal removal by nodulated *Mimosa pudica*. *J. Hazard. Mater.* **2008**, *151*, 364–371. [\[CrossRef\]](#)
192. Santra, H.K.; Banerjee, D. Induction of stress tolerance in plants by endophytes for sustainable development. In *Endophytic Association: What, Why and How*; Academic Press: Amsterdam, The Netherlands, 2023; pp. 533–554.
193. Liang, X.; Chi-Quan, H.E.; Gang, N.I.; Tang, G.E.; Xue-Ping, C.H.E.N.; Yan-Ru, L.E.I. Growth and Cd accumulation of *Orychophragmus violaceus* as affected by inoculation of Cd-tolerant bacterial strains. *Pedosphere* **2014**, *24*, 322–329. [\[CrossRef\]](#)
194. Weyens, N.; van der Lelie, D.; Taghavi, S.; Vangronsveld, J. Phytoremediation: Plant–endophyte partnerships take the challenge. *Curr. Opin. Biotechnol.* **2009**, *20*, 248–254. [\[CrossRef\]](#)
195. Khan, A.R.; Ullah, I.; Khan, A.L.; Park, G.S.; Waqas, M.; Hong, S.J.; Jung, B.K.; Kwak, Y.; Lee, I.J.; Shin, J.H. Improvement in phytoremediation potential of *Solanum nigrum* under cadmium contamination through endophytic-assisted *Serratia* sp. RSC-14 inoculation. *Environ. Sci. Pollut. Res.* **2015**, *22*, 14032–14042. [\[CrossRef\]](#) [\[PubMed\]](#)
196. Chen, L.; Luo, S.; Xiao, X.; Guo, H.; Chen, J.; Wan, Y.; Li, B.; Xu, T.; Xi, Q.; Rao, C.; et al. Application of plant growth-promoting endophytes (PGPE) isolated from *Solanum nigrum* L. for phytoextraction of Cd-polluted soils. *Appl. Soil Ecol.* **2010**, *46*, 383–389. [\[CrossRef\]](#)
197. Luo, S.; Wan, Y.; Xiao, X.; Guo, H.; Chen, L.; Xi, Q.; Zeng, G.; Liu, C.; Chen, J. Isolation, and characterization of endophytic bacterium LRE07 from cadmium hyperaccumulator *Solanum nigrum* L. and its potential for remediation. *Appl. Microbiol. Biotechnol.* **2011**, *89*, 1637–1644. [\[CrossRef\]](#) [\[PubMed\]](#)
198. Visioli, G.; D'Egidio, S.; Vamerali, T.; Mattarozzi, M.; Sanangelantoni, A.M. Culturable endophytic bacteria enhance Ni translocation in the hyperaccumulator *Noccaea caerulescens*. *Chemosphere* **2014**, *117*, 538–544. [\[CrossRef\]](#) [\[PubMed\]](#)
199. Ma, Y.; Oliveira, R.S.; Nai, F.; Rajkumar, M.; Luo, Y.; Rocha, I.; Freitas, H. The hyperaccumulator *Sedum plumbizincicola* harbors metal-resistant endophytic bacteria that improve its phytoextraction capacity in multi-metal contaminated soil. *J. Environ. Manag.* **2015**, *156*, 62–69. [\[CrossRef\]](#) [\[PubMed\]](#)
200. Yang, C.; Ho, Y.N.; Makita, R.; Inoue, C.; Chien, M.F. A multifunctional rhizobacterial strain with wide application in different ferns facilitates arsenic phytoremediation. *Sci. Total Environ.* **2020**, *712*, 1–11. [\[CrossRef\]](#)
201. Vurukonda, S.S.K.P.; Vardharajula, S.; Shrivastava, M.; SkZ, A. Enhancement of drought stress tolerance in crops by plant growth promoting rhizobacteria. *Microbiol. Res.* **2016**, *184*, 13–24. [\[CrossRef\]](#)
202. Jha, Y.; Subramanian, R.B. PGPR regulate caspase-like activity, programmed cell death, and antioxidant enzyme activity in paddy under salinity. *Physiol. Mol. Biol. Plants* **2014**, *20*, 201–207. [\[CrossRef\]](#)
203. Ait Barka, E.; Nowak, J.; Clément, C. Enhancement of chilling resistance of inoculated grapevine plantlets with a plant growth-promoting rhizobacterium, *Burkholderia phytofirmans* strain PsJN. *Appl. Environ. Microbiol.* **2006**, *72*, 7246–7252. [\[CrossRef\]](#)
204. Kour, D.; Rana, K.L.; Yadav, A.N.; Yadav, N.; Kumar, V.; Kumar, A.; Sayyed, R.Z.; Hesham, A.E.L.; Dhaliwal, H.S.; Saxena, A.K. Drought-tolerant phosphorus-solubilizing microbes: Biodiversity and biotechnological applications for alleviation of drought stress in plants. In *Plant Growth Promoting Rhizobacteria for Sustainable Stress Management*; Springer: Singapore, 2019; pp. 255–308.
205. Chouychai, W.; Sangdee, A.; Phunee, A.; Senarit, P.; Somtrakoon, K. Using *Streptomyces* spp. as Plant Growth-Promoting Inoculants for Growth of Napier Grass under Low Water System. *Pertanika J. Trop. Agric. Sci.* **2022**, *45*, 491–504. [\[CrossRef\]](#)
206. Saravanakumar, D.; Kavino, M.; Raguchander, T.; Subbian, P.; Samiyappan, R. Plant growth promoting bacteria enhance water stress resistance in green gram plants. *Acta Physiol. Plant.* **2011**, *33*, 203–209. [\[CrossRef\]](#)
207. Guleria, I.; Kumari, A.; Lacaille-Dubois, M.A.; Kumar, V.; Saini, A.K.; Dhatwalia, J.; Lal, S. A review on the genus *Populus*: A potential source of biologically active compounds. *Phytochem. Rev.* **2021**, *21*, 987–1046. [\[CrossRef\]](#)
208. Sheng, X.F.; Jiang, C.Y.; He, L.Y. Characterization of plant growth-promoting *Bacillus edaphicus* NBT and its effect on lead uptake by Indian mustard in a lead-amended soil. *Can. J. Microbiol.* **2008**, *54*, 417–422. [\[CrossRef\]](#) [\[PubMed\]](#)
209. Ahemad, M.; Iqbal, J. Phosphate-solubilizing bacteria as plant growth promoters and accelerators of phytoremediation. In *Phytoremediation of Environmental Pollutants*; CRC Press: Boca Raton, FL, USA, 2017; pp. 227–244.

210. Joe, M.M.; Islam, M.R.; Karthikeyan, B.; Bradeepa, K.; Sivakumaar, P.K.; Sa, T. Resistance responses of rice to rice blast fungus after seed treatment with the endophytic *Achromobacter xylosoxidans* AUM54 strains. *Crop Prot.* **2012**, *42*, 141–148. [\[CrossRef\]](#)
211. Siciliano, S.D.; Germida, J.J. Enhanced phytoremediation of chlorobenzoates in rhizosphere soil. *Soil Biol. Biochem.* **1999**, *31*, 299–305. [\[CrossRef\]](#)
212. Rentz, J.A.; Alvarez, P.J.; Schnoor, J.L. Repression of *Pseudomonas putida* phenanthrene-degrading activity by plant root extracts and exudates. *Environ. Microbiol.* **2004**, *6*, 574–583. [\[CrossRef\]](#)
213. Taghavi, S.; Barac, T.; Greenberg, B.; Borremans, B.; Vangronsveld, J.; van der Lelie, D. Horizontal gene transfer to endogenous endophytic bacteria from poplar improves phytoremediation of toluene. *Appl. Environ. Microbiol.* **2005**, *71*, 8500–8505. [\[CrossRef\]](#)
214. Weyens, N.; Truyens, S.; Saenen, E.; Boulet, J.; Dupae, J.; Taghavi, S.; van der Lelie, D.; Carleer, R.; Vangronsveld, J. Endophytes and their potential to deal with co-contamination of organic contaminants (toluene) and toxic metals (nickel) during phytoremediation. *Int. J. Phytoremediation* **2011**, *13*, 244–255. [\[CrossRef\]](#) [\[PubMed\]](#)
215. Afzal, M.; Yousaf, S.; Reichenauer, T.G.; Sessitsch, A. Ecology of alkane-degrading bacteria and their interaction with the plant. *Mol. Microb. Ecol. Rhizosphere* **2013**, *2*, 975–989.
216. Manzoor, M.; Gul, I.; Ahmed, I.; Zeeshan, M.; Hashmi, I.; Amin, B.A.Z.; Kallerhoff, J.; Arshad, M. Metal tolerant bacteria enhanced phytoextraction of lead by two accumulator ornamental species. *Chemosphere* **2019**, *227*, 561–569. [\[CrossRef\]](#)
217. He, L.Y.; Zhang, Y.F.; Ma, H.Y.; Chen, Z.J.; Wang, Q.Y.; Qian, M.; Sheng, X.F. Characterization of copper-resistant bacteria and assessment of bacterial communities in rhizosphere soils of copper-tolerant plants. *Appl. Soil Ecol.* **2010**, *44*, 49–55. [\[CrossRef\]](#)
218. Sun, L.N.; Zhang, Y.F.; He, L.Y.; Chen, Z.J.; Wang, Q.Y.; Qian, M.; Sheng, X.F. Genetic diversity and characterization of heavy metal-resistant endophytic bacteria from two copper-tolerant plant species on copper mine wasteland. *Bioresour. Technol.* **2010**, *101*, 501–509. [\[CrossRef\]](#)
219. Sheng, X.; Chen, X.; He, L. Characteristics of an endophytic pyrene-degrading bacterium of *Enterobacter* sp. 12J1 from *Allium macrostemon* Bunge. *Int. Biodeterior. Biodegrad.* **2008**, *62*, 88–95. [\[CrossRef\]](#)
220. Yousaf, S.; Andria, V.; Reichenauer, T.G.; Smalla, K.; Sessitsch, A. Phylogenetic and functional diversity of alkane degrading bacteria associated with Italian ryegrass (*Lolium multiflorum*) and Birdsfoot trefoil (*Lotus corniculatus*) in a petroleum oil-contaminated environment. *J. Hazard. Mater.* **2010**, *184*, 523–532. [\[CrossRef\]](#) [\[PubMed\]](#)
221. Wu, X.Q.; Yuan, W.M.; Tian, X.J.; Fan, B.; Fang, X.; Ye, J.R.; Ding, X.L. Specific and functional diversity of endophytic bacteria from pine wood nematode *Bursaphelenchus xylophilus* with different virulence. *Int. J. Biol. Sci.* **2013**, *9*, 34. [\[CrossRef\]](#) [\[PubMed\]](#)
222. Moore, F.P.; Barac, T.; Borremans, B.; Oeyen, L.; Vangronsveld, J.; Van der Lelie, D.; Campbell, C.D.; Moore, E.R. Endophytic bacterial diversity in poplar trees growing on a BTEX-contaminated site: The characterization of isolates with potential to enhance phytoremediation. *Syst. Appl. Microbiol.* **2006**, *29*, 539–556. [\[CrossRef\]](#)
223. Khan, Z.; Roman, D.; Kintz, T.; delas Alas, M.; Yap, R.; Doty, S. Degradation, phytoprotection and phytoremediation of phenanthrene by endophyte *Pseudomonas putida*, PD1. *Environ. Sci. Technol.* **2014**, *48*, 12221–12228. [\[CrossRef\]](#) [\[PubMed\]](#)
224. Rajkumar, M.; Ae, N.; Freitas, H. Endophytic bacteria and their potential to enhance heavy metal phytoextraction. *Chemosphere* **2009**, *77*, 153–160. [\[CrossRef\]](#)
225. Babu, A.G.; Kim, J.D.; Oh, B.T. Enhancement of heavy metal phytoremediation by *Alnus firma* with endophytic *Bacillus thuringiensis* GDB-1. *J. Hazard. Mater.* **2013**, *250*, 477–483. [\[CrossRef\]](#)
226. Singh, D.; Singh, V.K.; Singh, A.K. Endophytic Microbes: Prospects and Their Application in Abiotic Stress Management and Phytoremediation. In *Seed Endophytes*; Springer: Cham, Switzerland, 2013; pp. 313–333.
227. Ma, Y.; Rajkumar, M.; Zhang, C.; Freitas, H. Beneficial role of bacterial endophytes in heavy metal phytoremediation. *J. Environ. Manag.* **2016**, *174*, 14–25. [\[CrossRef\]](#) [\[PubMed\]](#)
228. Luo, S.L.; Chen, L.; Chen, J.L.; Xiao, X.; Xu, T.Y.; Wan, Y.; Rao, C.; Liu, C.B.; Liu, Y.T.; Lai, C.; et al. Analysis and characterization of cultivable heavy metal-resistant bacterial endophytes isolated from Cd-hyperaccumulator *Solanum nigrum* L. and their potential use for phytoremediation. *Chemosphere* **2011**, *85*, 1130–1138. [\[CrossRef\]](#) [\[PubMed\]](#)
229. Zhang, Y.F.; He, L.Y.; Chen, Z.J.; Zhang, W.H.; Wang, Q.Y.; Qian, M.; Sheng, X.F. Characterization of lead-resistant and ACC deaminase-producing endophytic bacteria and their potential in promoting lead accumulation of rape. *J. Hazard. Mater.* **2011**, *186*, 1720–1725. [\[CrossRef\]](#)
230. He, L.; Ren, Y.; Zeng, W.; Wu, X.; Shen, L.; Yu, R.; Liu, Y.; Li, J. Deciphering the endophytic and rhizospheric microbial communities of a Metallophyte *Commelina communis* in different Cu-polluted soils. *Microorganisms* **2021**, *9*, 1689. [\[CrossRef\]](#)
231. Bisht, S.; Pandey, P.; Kaur, G.; Aggarwal, H.; Sood, A.; Sharma, S.; Kumar, V.; Bisht, N.S. Utilization of endophytic strain *Bacillus* sp. SBER3 for biodegradation of polyaromatic hydrocarbons (PAH) in soil model system. *Eur. J. Soil Biol.* **2014**, *60*, 67–76. [\[CrossRef\]](#)
232. Kuffner, M.; De Maria, S.; Puschenreiter, M.; Fallmann, K.; Wieshammer, G.; Gorfer, M.; Strauss, J.; Rivelli, A.R.; Sessitsch, A. Culturable bacteria from Zn- and Cd-accumulating *Salix caprea* with differential effects on plant growth and heavy metal availability. *J. Appl. Microbiol.* **2010**, *108*, 1471–1484. [\[CrossRef\]](#) [\[PubMed\]](#)
233. Ruppel, S.; Franken, P.; Witzel, K. Properties of the halophyte microbiome and their implications for plant salt tolerance. *Funct. Plant Biol.* **2013**, *40*, 940–951. [\[CrossRef\]](#) [\[PubMed\]](#)

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.